Sympathy for the devil

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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Hortensius, R. (2016). *Sympathy for the devil: On the neural mechanisms of threat and distress reactivity*. GVO drukkers & vormgevers B.V. | Ponsen & Looijen.


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On the Neural Mechanisms
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ISBN	978-90-6464-993-6
Cover illustration	Ronald Huiskes *www.ronaldhuiskes.nl*
Printing	GVO drukkers & vormgevers B.V. | Ponsen & Looijen

This dissertation was supported by the European Union's Seventh Framework Programme (grant numbers: 249858 and 295673) and an Erasmus+ staff mobility grant.

Sympathy for the Devil

On the Neural Mechanisms of Threat and Distress Reactivity

Proefschrift

ter verkrijging van de graad van doctor aan Tilburg University
op gezag van de rector magnificus, prof.dr. E.H.L. Aarts,
in het openbaar te verdedigen ten overstaan van een door het college voor promoties
aangewezen commissie in de aula van de Universiteit

op woensdag 13 april 2016 om 14.15 uur

door Ruud Hortensius,
geboren op 3 september 1983 te Wageningen

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Prof. dr. J.B. Rijsman

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Voor *Merel*

Action is my middle name

– *Morrissey, 2011*

Chapter 1

General introduction

Introduction

As thousands of commuters will testify, fellow humans can both amaze and irritate. Empathy and aggression are everywhere. This ostensible positive versus negative dichotomy of social interaction is all-encompassing. As an echo of the diversity of social life, one could also look at the online world. The videos that people watch represent the sharp contrast in pro- and antisocial interaction. 'Hooligans fighting' is one click away from 'humans are awesome'. Similarly, websites range from crowd-funding a treatment for a child with a rare disease to hate-filled gatherings of angry and confused people.

We, *Homo sapiens*, are a social species. We spend our entire lives in a vast social environment. From our homes to our schools, from our work to our online life, it revolves around interaction with other people. Humans have a fundamental 'need to belong' (Baumeister & Leary, 1995). Indeed, loneliness has a profound effect on emotion, cognition and physiology (Hawkley & Cacioppo, 2010), and can even lead to cardiovascular problems (Cacioppo et al., 2002) and depressive symptoms (Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006). On the other hand, when two or more individuals interact a complex interplay between expression and perception of emotional signals occurs. This will lead to a cascade of positive and negative behavioral consequences. A simple heuristic is to view social interaction as a scale with each side representing the positive and negative aspect that shift the overall balance over time. The most striking ones are empathy- and aggression-related. We help each other, but also kill each other. Or, pertaining more to daily life, you can feel fear and show a freezing response when threatened, feel angered and react aggressively when you are wrongfully accused, or feel sympathy and offer help when observing the distress signals of a person in need.

Needless to say, understanding the mechanisms underlying social interaction is of crucial importance to society. The study of brain processes underlying social interaction will not only provide fundamental insight into human nature, it will offer new ways of predicting and manipulating human behavior (Stanley & Adolphs, 2013). The goal of this thesis is to provide insight into the neural mechanisms underlying both the negative and positive consequences of social interaction. The negative social interactions (part I) in this thesis comprise the perception of and reaction to threat signals, fear and anger, and dominance behavior, while the positive social interactions (part II) convey the perception of and reaction to signals of distress and helping behavior. In short, how do we perceive and react to threat and distress? The social situations in this thesis range from prototypical expressions to complex social interactions, from a threatening individual to an emergency situation with multiple bystanders to a violent conflict between individuals. In the remainder of this chapter, the research topics will be introduced and a foundation for the work in this thesis will be provided. A theoretical framework, a brief review of the neural networks involved, as well as the aims of the separate studies will be described.

The emotional life

While humans are social animals, we do not live in an evolutionary vacuum. The behavioral patterns studied in this thesis are not uniquely human. Precursors to human social behavior as well as homologous behavior are observed across the animal kingdom (Darwin, 1872/2009; Panksepp, 1998). Indeed this is the case for negative aspects, e.g., defensive, aggressive, and dominance behavior (Eibl Eibesfeldt, 1977; Mazur & Booth, 1998; N. McNaughton & Corr, 2004), as well as for positive aspects such as (rough-and-tumble) play (Panksepp, Siviy, & Normansell, 1984; S. M. Pellis & Pellis, 1998), and even functional altruism (de Waal, 2008; 2015; Preston & de Waal, 2002). A large body of knowledge, derived from diverse research domains, provides evidence for the notion of phylogenetically ancient mechanisms underlying the positive and negative aspects of social interaction.

Emotions are the building blocks of social interaction. Throughout this thesis it will be stressed that the crucial aspect of any social emotional situation is the individual's response. The emotional value, whether psychological constructs (Barrett et al., 2007) or natural kinds (Panksepp, 2007), signals the relevance of a situation or interaction to the observer who then either approaches or avoids the situation. This approach versus avoidance distinction serves as a common theme throughout this thesis, both for the positive and negative social interactions. Action is the middle name of emotion and social interaction. What are some of the important proximate mechanisms? How do we get from perception to action? In the following section, the Defensive or Fight/Freezing/Flight System, and the Dual-Process Sequential Opponent Motivational System, will be briefly described. Together these systems help explain the occurrence of approach and avoidance behavior in situations as diverse as a confrontation with an aggressive individual to the observation of distress in an older woman.

Fight, flight, or freeze

From startle responses to noise blasts, to arm movements to protect the body, to clenched fists and dominance postures, defensive behaviors, actions that are to protect the individual, occur in the response to a variety of situations. In response to physical threat (ball thrown) as well as social threat (angry person). The majority of these responses are innate or unconditioned. For example, rats that never encountered a cat show freeze and avoidant responses when placed in a room with a cat (R. J. Blanchard & Blanchard, 1971). Defensive behavior is the results of two systems. The first categorical system, approach versus avoidance, is complemented by a second system, defensive distance (N. McNaughton & Corr, 2004). While the former deals with fight, freeze and flight responses to threat, the latter deals with the perceived intensity of threat as a function of distance. Reactions to threat are a direct consequence of both systems. For defensive avoidance, medium intensity threat at intermediate distance results in flight, while the same situation results in a freezing response when flight is not available. Defensive attack occurs in the face of high intensity threat at close distance. A similar division can be made for defensive approach, with high intensity threat at close range resulting in quietness,

while medium intensity threat at a further distance results in risk assessment (N. McNaughton & Corr, 2004). Importantly, this translational model of defensive responses maps onto human behavior (R. J. Blanchard & Blanchard, 1989). Not only provide humans answers in response to hypothetical threat that correspond to the defensive system found in animals (D. C. Blanchard, Hynd, Minke, Minemoto, & Blanchard, 2001), similar behavioral responses or proxies of have been observed (Bradley, Codispoti, Cuthbert, & Lang, 2001). For example, a freezing response, as defined by reduced body sway and hear rate deceleration has been observed in response to facial signals of anger (Roelofs, Hagenaars, & Stins, 2010) and films negative in valence (Hagenaars, Roelofs, & Stins, 2014). Similarly, an approach-avoidance contingency (fight-flight) has been described in humans in response to a variety of situations (Bradley et al., 2001; Carver, 2006; van Honk & Schutter, 2007). The confrontation with social emotional situation (threat, distress) induces a cascade of physiological changes (Panksepp, 1998; Preston & de Waal, 2002), that prepare the individual to respond adaptively. One such mechanism is preparation for action (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Frijda, 1986; Grèzes & Dezecache, 2014; Hajcak et al., 2007; Lang, Greenwald, Bradley, & Hamm, 1993; Schutter, Hofman, & van Honk, 2008b), a process that, as will be shown, allows the individual to deal with incoming threat and extend the behavioral repertoire.

Sympathy versus Distress

A related model focused on the positive dimension, the Dual-Process Sequential Opponent Motivational System (W. G. Graziano & Habashi, 2010; W. G. Graziano & Tobin, 2009), helps explain the occurrence of prosocial behavior. This system nicely incorporates findings in the literature on threat and defensive behavior (N. McNaughton & Corr, 2004), motivation (Solomon, 1980; Solomon & Corbit, 1974), and parental care (Preston, 2013). When an individual is confronted with distress in the environment, two interrelated, but opposing, systems are activated. The first and fastest system (process A) overlaps with the Fight/Freezing/Flight System. When activated the individual will feel distress and the behavioral response is limited due to the occurrence of a freezing response. Under these conditions helping and other prosocial behaviors do not occur. Over time a second, but slower, evolutionary conserved motivational system, linked to parental care is activated. This system (process B) opposes the inhibitory function of process A and is related to feelings of sympathy. A stronger activation of this system will increase the likelihood of prosocial behavior. Crucially, these opposing feelings, sympathy versus distress, are observed in concert in the individual when confronted with an emergency. It is the net sum of these two systems that determines the behavioral probability. This model is in line with the distinction between sympathy and personal distress in terms of motivation (C. D. Batson, Fultz, & Schoenrade, 1987). Sympathy is an other-oriented response and comprises feelings of compassion and care for another individual, while personal distress is a self-oriented response and relates to feelings of discomfort and distress in the observer. The dual-process system suggests that both sympathy and personal distress occur in every individual and, as will be shown, this explains a variety of phenomena ranging from contextual effects to inter-individual differences.

The brain and social emotional situations

The brain is a tool to predict and react to present and future situations (for example Schacter, Addis, & Buckner, 2007). While previous studies take the perspective of distinct social or emotional brain regions, this thesis adopts a different approach and studies the close interplay between action and social and emotional processes by stressing the reactive aspect of social interaction. Or as stated elsewhere:

> Our perspective is that social interaction abilities are part and parcel of the evolutionary endowment of the species. The consequence of this is that the neuroscience community needs to confront the fact that the brain's natural task is thus not labeling prototypical emotions but registering and responding to the interactive emotional coloring that is part of daily communication
>
> – de Gelder and Hortensius, 2014, p. 161

There is no social brain. Likewise, there is no emotional brain. Brain regions serve multiple functions. Indeed, this is reflected in large-scale automated term-based meta-analytic brain activation maps that were created using the 'Neurosynth' database (http://neurosynth.org), a large database on the inference of concepts on brain regions derived from the literature using text-mining and meta-analysis (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Forward inference maps of the terms 'social', 'emotion', and 'action', indicating the likelihood of activation if a study uses the term, show largely overlapping maps (**Figure 1A**). The activation of a variety of occipital, parietal and pre(frontal) regions provides evidence for a functional convergence of social, emotional and action processes. Importantly, several key regions such as the amygdala (AMG), the medial prefrontal cortex (MPFC), and secondary motor areas are activated in at least two maps. In this section several important regions and networks combined into a working model will be described, partly based on the dual route of affective perception (de Gelder, Hortensius, & Tamietto, 2012), a framework that highlights the importance of conserved neural mechanisms in the expression and perception of social emotional signals, and reaction to these salient signals.

While the model in de Gelder, Hortensius and Tamietto (2012) deals with bodily expressions of emotion, a similar model has been described for facial expressions (de Gelder & Rouw, 2001; Vuilleumier, 2005). It is likely that aspects of the dual route of affective perception deal with visual emotional signals per se rather than distinct categories (Dalgleish, 2004; Tamietto & de Gelder, 2010), and this provides a suitable starting point for the work presented in this thesis. When confronted with a threatening or distressed individual, social emotion information is processed in a detection and recognition route. These routes correspond to a dorsal and ventral division in the brain (see Binkofski & Buxbaum, 2013; Goodale & Milner, 1992; Ungerleider & Mishkin, 1982). The first route comprises a superior colliculus (SC)

– pulvinar (Pulv) – AMG, and dorsal stream– orbitofrontal cortex (OFC) pathway with or without primary visual cortex input, and sustains early emotion processing. This is followed by late emotion processing in the AMG, OFC, posterior cingulate cortex, anterior insula and somatosensory regions. This rapid detection and integration of the social emotional information provides the input for reflexive defensive behavior mediated by the periaqueductal gray (PAG), putamen, and caudate nucleus. The second and parallel route is important for recognition and reflective action. Regions in the ventral stream, such as the extrastriate body area and superior temporal sulcus, together with the frontal-parietal attention network and frontal-parietal action network sustain a slower more careful analysis of the social emotional situation. This dual route of affective perception corresponds to a rough division in terms of reflexive and reflective processes. Together with other accounts (Grezes:2014hu; Grèzes, Adenis, Pouga, & Armony, 2013a) and recent evidence (de Gelder et al., 2004; M. I. Garrido, Barnes, Sahani, & Dolan, 2012; Grèzes, Pichon, & de Gelder, 2007; Grosbras & Paus, 2006; Pichon, de Gelder, & Grèzes, 2008; 2009; 2012; Rudrauf et al., 2008), it proposes that reactions to social emotional situations can be automatic, mediated by the first route, or the end result of a more deliberate mechanism driven by the second route. Shortcut exists between routes that allow the second route to trigger more reflexive action via part of the first route and vice versa. Thus, everything in between reflexive and reflective action is possible.

Several key regions that were activated in the term-based meta-analytic maps, but were previously not described in the dual route of affective perception (de Gelder et al., 2012), warrant discussion. While the regions highlighted above provide the framework for perception to action, these additional regions, the MPFC and clusters in secondary motor areas, extend the dual route perspective in important ways.

Using the well documented connections between the AMG and motor cortical areas (for example Avendaño, Price, & Amaral, 1983; H. T. Ghashghaei, Hilgetag, & Barbas, 2007; Llamas, Avendaño, & Reinoso-Suárez, 1985), Grèzes and colleagues (2014) studied the possible existence of a homologous pathway in humans. They showed direct anatomical connections between the AMG and primary and secondary motor areas. This pathway provides a direct way for the AMG to influence ongoing behavior that extend beyond reflexive reactions, but is still relatively independent from cognitive influences. Motor cortical areas have reliably been activated in response to social emotional information (for a review see Grèzes & Dezecache, 2014). Both studies that measured activation (Conty, Dezecache, Hugueville, & Grèzes, 2012; de Gelder et al., 2004; Grèzes et al., 2007; Grèzes, Adenis, Pouga, & Armony, 2013a; Pichon et al., 2008; 2009; 2012), as well as those that directly probed the human motor cortex (Baumgartner, Willi, & Jäncke, 2007; Borgomaneri, Gazzola, & Avenanti, 2012; 2014a; 2014b; Coelho, Lipp, Marinovic, Wallis, & Riek, 2010; Coombes et al., 2009; Enticott et al., 2012; Giovannelli et al., 2013; Hajcak et al., 2007; Schutter et al., 2008b; van Loon, van den Wildenberg, van Stegeren, Hajcak, & Ridderinkhof, 2010), provided evidence for the notion of preparation for action. For example, Schutter and colleagues (2008b) briefly presented faces

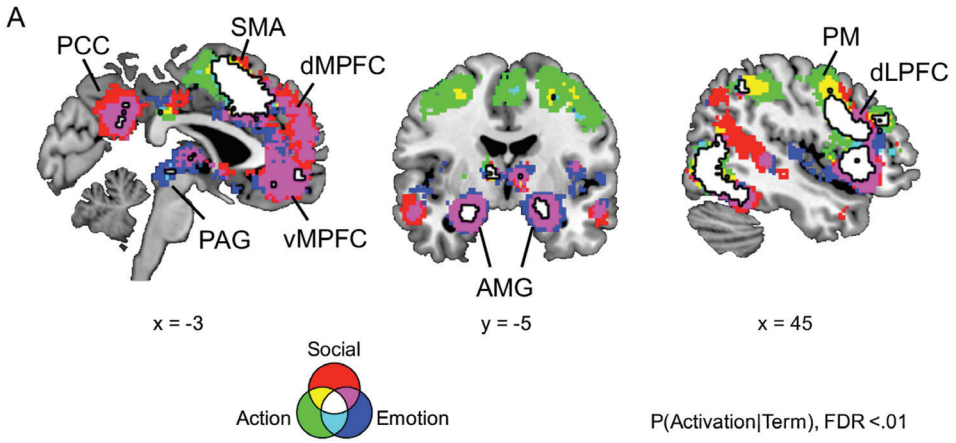
with a fearful, happy or neutral expressions to participants while simultaneously measuring motor corticospinal excitability levels. Results indicated that facial signals of fear selectively increase motor corticospinal excitability levels. This has been interpreted as a preparatory response (Hajcak et al., 2007). This action readiness or preparatory response is not limited to confrontations with threat, but is also likely to occur when confronted with the distress of another individual (Preston & de Waal, 2002). Indeed, motor corticospinal excitability levels increase both for negative and positive valenced pictures of affect (vanLoon:2010dg; Hajcak et al., 2007), showing the possible existence of a general preparatory mechanism. A review of premotor cortex activation in response to emotional displays of threat found mean coordinates corresponding to the ventral/dorsal premotor (PM) border (Grèzes & Dezecache, 2014). Stimulation of this region in monkeys results in movement to defend the body (Cooke & Graziano, 2004), and a general role in organization of defensive behavior including safeguarding of interpersonal space has been described (M. S. A. Graziano & Cooke, 2006).

Another region that is connected to the AMG and PAG among other regions (Gabbott, Warner, Jays, Salway, & Busby, 2005) and plays an important role in the translation of the perception of the social emotional situation to adaptive reactions is the MPFC. This region of the prefrontal cortex has been described as the visceral motor cortex (Neafsey, Terreberry, Hurley, Ruit, & Frysztak, 1993) and sustains situation-response coupling (W. H. Alexander & Brown, 2011; Euston, Gruber, & McNaughton, 2012). After initial processing by other nodes of the network, this region triggers the response in the individual based on previous experience with the situation and other contextual information. Together, the described neural network provides the necessary computations for behavioral reactivity to confrontations with salient situations (**Figure 1B**).

Outline of this thesis

As the goal of this thesis is to provide insight into the neural mechanisms of social interaction, a multidimensional framework is used. Naturalistic stimuli together with a variety of techniques from experimental and social psychology, and affective and social neuroscience are used to approximate and study the natural richness of social emotional life. Together these studies eventually work towards a novel understanding of active and everyday social interaction both positive and negative in nature (de Gelder & Hortensius, 2014).

The first part, **chapter 2 – 4**, focuses on the negative aspects of social interaction. How is the human brain evolutionary endowed to cope with threat? While most of us would argue to be rational beings, our daily life suggests otherwise. The majority of behavioral reactions to situations serve as a function of evolutionary conserved mechanisms. **Chapters 2** and **3** measure reflexive reactions to threat as function of threat direction as well as the personality



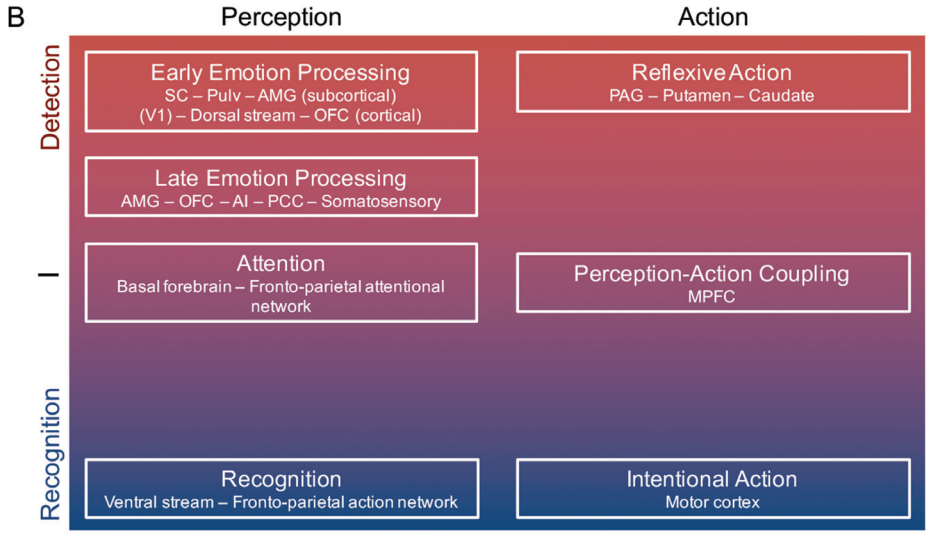


Figure 1. The neural system for perception of and reaction to social emotional situations. Meta-analytic brain activation maps for the terms 'social', 'emotion', and 'action' (A) and working model (B). Automated term-based meta-analytic brain activation maps were created and downloaded from the 'Neurosynth' database (http://neurosynth.org) on August 16 2015. The terms are automatically extracted from scientific articles and reflect the topic under study and can be used to create meta-analytic maps. The maps are based on 1000 studies for 'social', 790 studies for 'emotion', and 708 studies for 'action'. P(Activation|Term) is reported and maps are corrected at $p < .01$ FDR. Only some of the relevant regions are labeled and color-coding denotes term-based maps and overlap. The working model (based on de Gelder et al., 2012) describes two parallel routes that mediate perception-to-action. The first route corresponds to detection of the signal and rapid reflexive reaction, while the second route plays a role in recognition and deliberate and reflective reactions. Attention and perception-action coupling lie on the border between the detection and recognition route. SMA: supplemental motor area, dMPFC: dorsal medial prefrontal cortex, vMPFC: ventral medial prefrontal cortex, PAG: periaqueductal gray, AMG: amygdala, PM: premotor cortex, SC: superior colliculus, Pulv: pulvinar, OFC: orbitofrontal cortex, AI: anterior insular, PCC: posterior cingulate cortex.

of the observer. Related, **chapter 4** investigates the processing of social threat after damage to a key region in the described neural pathway, the amygdala. Together, this part focuses on the first route of the working model and the defensive or Fight/Freezing/Flight system.

Chapter 2 investigates defensive behavior in response to threat directed towards or away from the individual. Both the perceptual and reactive consequences of threat direction are assessed. Single-pulse TMS, to assess motor corticospinal excitability as indexed by motor evoked potentials (MEPs) amplitude, is complimented by an explicit recognition task. Do both these measures serve as a function of threat direction? Importantly, do motor corticospinal excitability levels only increase when threat is directed towards the observer or is there a general defensive mechanism that is activated regardless of threat direction? Taking into account the personality of the observer, **chapter 3** focuses on reflex-like dominance behavior in response to facial and bodily displays of threat. Facial and bodily expressions play an important role in forming and maintaining patterns of dominance and submission. Gaze-aversion from these signals is measured in an interactive eye-tracking task to test the hypothesis if dominant individuals show similar reflex-like gaze behavior to non-conscious confrontations with bodily expressions of anger as to facial expressions of anger. In a follow-up study the need for detection and recognition of threat in the occurrence of dominance behavior is established. The last chapter of the first part, **chapter 4**, describes a unique report on social threat perception after bilateral damage to the amgydala. While previous studies have defined the amygdala as one homogenous structure, it can and needs to be further divided into at least three anatomical subnuclei each with a distinct functional role. In this study, functional magnetic resonance imaging (fMRI) is used to test deficits in functional segregation as well as integration in the processing of social threat in five participants with Urbach-Wiethe disease. As a result of this genetic disorder all five participants have a lesion in the basolateral amygdala (BLA), a part of the amygdala with crucial contributions to the processing of threat. Functional analysis and connectivity analyses are used to investigate the neural signature of a deficit in ignoring threat signals.

Diverging the attention to positive aspects of social interaction, the second part, **chapter 5 – 7**, reports on studies that investigate the reaction to distress and helping behavior in a variety of contexts. When asked almost everybody will say she or he will provide help when confronted with a future emergency situation. While mentally a hero, we often refrain from helping in real-life. One such example is the bystander effect, the decrease in helping behavior when several onlookers are present during an emergency (Darley & Latané, 1968). While this effect has been extensively studied from a situational approach in the last ~50 years (Fischer et al., 2011), several aspects remain ill understood. **Chapter 5** and **6** provide insights into neural mechanisms and dispositional factors that play an important but often neglected role in the occurrence of the bystander effect. In **chapter 7** predictions derived from the previous two chapters were tested. This last part deals with the interplay of route I and II, as well as the theoretical framework of the Dual-Process Sequential Opponent Motivational System.

Chapter 5, reports on the first ever fMRI study on the bystander effect. Participants performed a color-naming task while implicitly observing an emergency situation in which the number of bystanders was parametrically varied. This study tests the novel hypothesis if an increase in group size during an emergency will decrease activity in regions important for preparation for action. **Chapter 6** is a follow-up study that investigates dispositional and situational factors that influence the occurrence of helping behavior. In a series of four experiments, the influence of sympathy and personal distress on responding to an emergency with bystanders is investigated. To this goal, a novel cued-reaction time task was created that allows the measure of preparatory responses as a function of the emergency situation. At a later stage a cognitive load manipulation is added to test the influence of cognitive processes on the ostensible relation between personal distress and the negative effect of bystanders. This is complemented with a direct measures of the motor system using single-pulse TMS. Overall it is hypothesized that personal distress, but not sympathy, will be related to a negative effect of bystanders. In the final chapter of the second part, **chapter 7**, the previous two studies are combined to investigate the prediction of helping behavior during a violent conflict. Importantly, this chapter goes beyond the status quo and pays tribute to the notion that interactions are in essence affective loops. Therefore, Immersive Virtual Reality (IVR) was used. IVR is a state-of-the-art technique that allows researchers to create ecologically and methodologically sound environments to study complex social behaviors under strict control (Blascovich et al., 2002). This chapter examines if individual differences in reflexive behavioral reactivity to an emergency situation can be used to predict later helping behavior during a violent conflict between an aggressor and victim. In addition, the relation between self-reported decision-making style and helping behavior is assessed. Proxemics measurement, interpersonal distance to the victim and aggressor, is also used to allow for a throughout analyses.

In **Table 1** an overview of the individual chapters and research topics is presented. A general discussion on the empirical findings of the first and second part of the thesis with theoretical implications will be provided in **chapter 8**. Moreover, several directions for the future of social affective neuroscience will be described.

Table 1. Overview of the individual chapters with objects, techniques with measures, and sample.

Chapter	*Objective*	*Techniques*	*Measures*	*Sample*
Part I	**The Devil – Threat**			
2	Measure motor corticospinal excitability as a function of threat direction	TMS; behavioral testing	MEP amplitude; emotion recognition accuracy	Healthy participants
3	Assess the effect of trait dominance on reflexive staring with angry facial and bodily expressions	Eye-tracking; behavioral testing; personality measures	Gaze duration; detection sensitivity and emotion recognition accuracy; trait dominance	Healthy participants
4	Investigate the neural mechanisms of social threat perception after basolateral amygdala damage	fMRI	Functional activation and connectivity	Participants with UWD and matched controls
Part II	**Sympathy – Distress**			
5	Study the influence of group size on neural activity when witnessing an emergency	fMRI	Functional activation	Healthy participants
6	Investigate the relation between personal distress and the influence of bystanders on responding to an emergency	Behavioral testing; TMS; personality measures	Reaction times; MEP amplitude; trait empathy	Healthy participants
7	Use behavioral reactivity to an emergency to predict later helping behavior during a violent conflict	Behavioral testing; IVR; proxemics; personality measures	Number of interventions; reaction times; decision-making; interpersonal distance; trait empathy	Healthy supporters of F.C. Barcelona

Part I

The Devil - Threat

Doorslaggevende plekken in een individuele anatomie? In de eerste plaats het hoofd, of liever de schedel, dat geheel van botten dat het instrument om de wereld waar te nemen beschermt. Het is echter niet de intelligentie of het uitzonderlijke abstractievermogen maar het eenvoudige, oude afweermechanisme tegen de buitenwereld, de nog in die intelligentie aanwezige stoffelijke, dierlijke afweer die beschermd moet worden. Voor een analfabeet of iemand die niet kan rekenen, kan het hoofd toch nog de doorslaggevende plek zijn, zolang hij een geweer kan pakken en de bajonet van de kolf en de trekker van de loop kan onderscheiden. Het hoofd zit bomvol vermogens en verassende omwegen – een stadsplattegrond waarop de steegjes tot in het oneindige uitwaaieren – maar wat telt is de hoofdweg: we hebben een brein om ons niet te laten doden. Dat vereist maximale vaardigheden van onze vijanden. Laten we het niet ingewikkeld maken, dacht Lenz in stilte. Het brein heeft, als je het nader bekijkt en echt begrijpt de vorm en de functie van een geweer, meer niet.

– G.M. Tavares - Leren bidden in het tijdperk van de techniek, 2012

Chapter 2

When anger dominates the mind -

Increased motor corticospinal excitability in the face of threat

This chapter is in revision as:
Hortensius R, & de Gelder B & Schutter DJLG. When anger dominates the mind – Increased motor corticospinal excitability in the face of threat.

Abstract

Threat demands fast and adaptive reactions that are manifested at the physiological, behavioral and phenomenological level and reckon with the direction of threat and severity to the individual. Here, we investigated the effects of threat directed towards or away from the observer on motor corticospinal excitability and explicit recognition. Sixteen healthy right-handed volunteers completed a transcranial magnetic stimulation (TMS) task and a separate three-alternative forced-choice emotion recognition task. Single-pulse TMS to the left primary motor cortex was applied to measure motor evoked potentials from the right abductor pollicis brevis in response to dynamic angry, fearful or neutral bodily expressions directed towards or away from the observer. Results showed that motor corticospinal excitability increased independent of direction of anger compared with both fear and neutral. In contrast, anger was better recognized when directed towards the observer compared with when directed away from the observer, while the opposite pattern was found for fear. The present results provided evidence on the differential effects of direction and threat on explicit recognition and motor corticospinal excitability. In the face of threat motor corticospinal excitability increased independently of the direction of anger, indicative of the importance of more automatic reactions to threat.

Introduction

> Evolution created several coherently operating neural systems that help orchestrate and coordinate perceptual, behavioral, and physiological changes that promote survival in the face of danger
>
> – Panksepp, 1998, p. 206

In the human brain both subcortical and cortical areas underlie defensive mechanisms when confronted with threat (de Gelder et al., 2004; Mobbs et al., 2007; Panksepp, 1998; Pichon et al., 2012). Adaptive reactions to threat depend on a balance between these areas (for example van Honk, Harmon-Jones, Morgan, & Schutter, 2010). Emotional reactions to threat, such as anger and fear are influenced by several factors, such as personality and interpretation (Dill, Anderson, Anderson, & Deuser, 1997; P. Hall & Davidson, 1996; Wilkowski, Robinson, Gordon, & Troop-Gordon, 2007). Furthermore, we decode and interpret threatening signals in a contextual setting (Kret & de Gelder, 2010; Righart & de Gelder, 2008a; 2008b; Sinke, Van den Stock, Goebel, & de Gelder, 2012; Van den Stock, Vandenbulcke, Sinke, & de Gelder, 2014a).

Previous research mainly looked at the processing of threat signals without taking into account the observers' perspective. Studies looked at threat per se rather than threat directed towards or away from the observer, which may introduce ambiguity of the threatening stimulus. The fearful face can, for instance, be interpreted in at least two ways: Fear as a consequence of a threat in the environment or as a consequence of an action of the observer. One way to take into account for the perspective of the observer is the use of gaze direction (Hadjikhani, Hoge, Snyder, & de Gelder, 2008; Langton, Watt, & Bruce, 2000; N'Diaye, Sander, & Vuilleumier, 2009).

For facial expressions of threat, gaze permits to disentangle the relevance with respect to the observer. A fearful facial expression with averted gaze signals a possible imminent threat in the environment, similar to an angry facial expression with direct gaze that signals direct threat to the observer. In line with this, angry faces with direct gaze and fearful faces with averted gaze are recognized faster (Adams & Kleck, 2003), rated as more intense (Adams & Kleck, 2005; see also Hess, Adams, & Kleck, 2007; N'Diaye et al., 2009; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007) and enhance rapid reactions to facial expressions (Soussignan et al., 2013). An fMRI study found increased activation to fearful facial expressions with averted compared to directed gaze not only in brain areas important for stimulus detection, but also action preparation (premotor and motor areas) (Hadjikhani et al., 2008). Similar results have been found when manipulating the relevance of angry bodily expressions (Grèzes, Adenis, Pouga, & Armony, 2013a; Grèzes, Philip, Chadwick, Dezecache, Soussignan, et al., 2013b). Similar to a dynamic dual route perspective of affective perception (de Gelder et al., 2012), Grèzes

and colleagues (2013a) showed that a first network encompassing the premotor area, inferior frontal gyrus, amygdala and temporal pole, is not necessarily modulated by relevance, but is of particular importance for rapid detection and responses to threat (Grèzes, Adenis, Pouga, & Armony, 2013a). The second, frontal-based, network is relevance-dependent and is suggested to code for somatic consequences of the emotional state in the observer and subsequent response selection. As the direction to and distance from the observer is of importance for emotional memory and the behavior consequence (fight, flight or freezing) of the perceived threat (Åhs, Dunsmoor, Zielinski, & LaBar, 2015; R. J. Blanchard & Blanchard, 1989), we aimed to extend previous findings by using the direction of the action as communicated by movement to investigate the effect of threat directed towards or away from the observer, on the level of physiology and explicit recognition.

To directly quantify the effect on motor corticospinal excitability levels when an individual is confronted with threat, we used single-pulse transcranial magnetic stimulation (TMS). When applied to the primary motor cortex (M1), motor neurons can be stimulated by delivering a strong, brief magnetic pulse to the scalp, leading to a motor evoked potential (MEP) that indexes motor corticospinal excitability (Hallett, 2000). Early findings by Fadiga and colleagues (1995) that action observation increased motor corticospinal excitability were extended by a later study showing effects of self-induced happiness and sadness on motor corticospinal excitability levels (Tormos, Cañete, Tarazona, Catalá, & Pascual-Leone, 1997). Indeed, motor corticospinal excitability levels have successfully served as a proxy for emotion-related action mechanisms in a variety of studies (Avenanti, Bueti, Galati, & Aglioti, 2005; Baumgartner et al., 2007; Borgomaneri et al., 2012; Coelho et al., 2010; Coombes et al., 2009; Enticott et al., 2012; Giovannelli et al., 2013; Hajcak et al., 2007; Overeem, Reijntjes, Huyser, Lammers, & van Dijk, 2004; Schutter et al., 2008b; van Loon et al., 2010). Furthermore, Schutter, Hofman and van Honk (2008b) showed that fearful facial expressions selectively increase motor corticospinal excitability suggesting increased action preparedness when confronted with threat (Hajcak et al., 2007).

In the present study we used single-pulse TMS to study the physiological consequence of threat directed towards or away from the observer. We showed participants dynamic video clips of social threat, with fear and anger as threat signals and measured motor corticospinal excitability levels and explicit recognition. The goal of our study was to address the question if motor corticospinal excitability levels and explicit recognition were directly related to the direction of threat. We anticipated that anger directed towards the observer and fear directed away from the observer is better recognized than vice versa. Importantly, can this incongruence effect be observed in changes in motor corticospinal excitability levels? More specifically, do motor corticospinal excitability levels only increase when anger is directed towards the observer and fear is directed away from the observer?

Material and Methods

Participants

Participants were recruited by advertisements around the Utrecht University campus and by means of word-of-mouth. Eighteen healthy right-handed volunteers (twelve women, four men), aged between 18 and 24 years, participated in exchange for course credits or payment. Participants had normal or corrected-to-normal vision, no contraindications for non-invasive brain stimulation (Keel, Smith, & Wassermann, 2001) or history of psychiatric or neurological disease. None of the participants were regular smokers or were on medications, except for women using oral contraceptives (n = 10). All participants received written and oral information prior to the study, but remained naïve about the aim of the study, and provided written informed consent. Stimulation parameters were in agreement with the International Federation of Clinical Neurophysiology safety guidelines (Rossi, Hallett, Rossini, Pascual-Leone, Safety of TMS Consensus Group, 2009) and the study was approved by the medical ethics committee of University Medical Center Utrecht and Utrecht University, Utrecht, the Netherlands, and was carried out in accordance with the standards set by the Declaration of Helsinki.

Stimuli

Dynamic emotional expressions directed towards or away from the observer were recorded as part of the creation of a larger stimulus database containing facial and bodily expressions (see Kret, Pichon, Grèzes, & de Gelder, 2011). In order to achieve natural expressions of emotions during the recording, actors read short emotion-inducing stories, were shown pictures of emotional scenes, and were coached throughout the recordings. Eight male actors expressed anger or fear towards or away from the observer by means of a forward or backward jump. Thus, we were able to create congruent and incongruent expressions of the emotion. In the congruent condition anger is expressed towards the observer (forward jump), while fear is expressed away from the observer (backward jump). In the incongruent condition, anger is expressed away from the observer and fear is expressed towards the observer. It is important to note that the perspective of the observer defines the direction of threat. Thus, the angry or fearful individual was moving towards the, or away from, the observer by means of a jump. Threat was always directed at the observer as the actor had directed gaze and a frontal body orientation. Only the direction of the jump differed between the threat directed towards and away the observer, as all other aspects were held constant. To allow controlling for movement, a neutral expression was also included. For each actor and emotion two different versions were recorded. Actors were dressed in black and filmed against a green background in a recording studio under controlled and standardized lighting conditions. Video clips (2s) were edited using Adobe After Effects CS5 (Adobe Systems Inc., San Jose, CA, USA). Faces were masked with Gaussian mask in order to focus on information communicated by the body. Duration of the clip was reduced to 300ms since previous studies found an increase in motor corticospinal tract excitability 300ms after stimulus onset (Oliveri et al., 2003; Schutter et al.,

2008b). The **Video** shows examples of the stimuli used.

Transcranial Magnetic Stimulation and Motor Evoked Potentials

A biphasic Neopulse magnetic brain stimulator (maximum output 4160 A peak/1750 VAC peak) with a modified 8-shaped iron core coil (Neopulse, Atlanta, GA, USA) was used for stimulation over the left M1. Motor evoked potentials were recorded with active Ag-AgCl electrodes (11 x 17mm) using an ActiveTwo system (BioSemi, Amsterdam, the Netherlands) from the right abductor pollicis brevis (APB) in a belly-tendon montage with the active electrode placed at the muscle belly of the right APB and the reference electrode located at the proximal phalanx of the thumb (Baumgartner et al., 2007; Hajcak et al., 2007; Schutter et al., 2008b). The ground electrode was attached to the wrist. Sampling rate was set at 2048 Hz and the signal was offline high-pass filtered (3dB cutoff frequency: 20 Hz, roll-off: 24 dB/octave).

Procedure

After explanation of the procedure by the experimenter, the participants provided written informed consent and answered several standard questions on present physical and mental well-being (including, hours of sleep and alcohol intake in last 24 hours, and current emotional state) as an additional check for exclusion criteria. Next, participants were seated in a comfortable dentist chair with their arms placed on the upper leg with the palm of the hand facing upward. Electromyogram electrodes were attached and the resting motor threshold of the left hemisphere was assessed (mean±SD percentage of maximum output: 49.21±7.04%), using the standardized visual thumb movement procedure (Schutter & van Honk, 2006). A passive viewing task was used and participants were instructed to relax their body, not focus on their hands, and fixate on the fixation cross shown continuously during the task. Single-pulse TMS over left M1 at an intensity of 120% MT was applied 300ms after stimulus onset. After completion of the TMS procedure, participants indicated the emotion (fear, anger or neutral) of the presented stimulus in a separate three alternative forced-choice task. Stimuli (16 per condition) were presented in random order with a fixation cross (TMS: 4800 – 5200ms; emotion recognition: 1000 – 1500ms) in between. Upon completion, participants were debriefed and received payment.

Video. Scan the QR code to see examples of the stimuli.

Data reduction and analysis

Data of two participants were removed due to noisy EMG signals and excessive muscle artifacts. MEP was quantified as the peak-to-peak amplitude (>50μV) of the maximal EMG response. Every trial was visually inspected and was done blind to the stimulus condition. Trials containing excessive background EMG and MEPs <50μV or outside of the expected time window were removed. Mean±SD percentage of included trials per condition across participants was 91.28±14.06%. As the data was significantly non-normal distributed, $D(16) = 0.26$, $p = .004$, MEPs were transformed into z-scores based on individual mean and standard deviation (cf. Burle, Bonnet, Vidal, Possamaï, & Hasbroucq, 2002; van Loon et al., 2010). In addition, mean rectified baseline EMG activity was epoched from 1010ms to 10ms prior to the TMS pulse in order to examine the possible effect of baseline EMG activity on the MEP (Orban de Xivry, Ahmadi-Pajouh, Harran, Salimpour, & Shadmehr, 2013).

For the emotion recognition data, we calculated the recognition accuracy (percentage correct) for each emotion as a function of direction. In addition, for each emotion an incongruence effect was calculated by subtracting recognition accuracy of expressions directed away from the observer from recognition accuracy of expression directed towards the observer. A positive value indicated better recognition when the emotion is expressed towards the observer, whereas a negative value indicated better recognition when the emotion is expressed away from the observer.

A general linear model (GLM) for repeated measurements with direction (2) and emotion (3) as within subject factors, was applied to both the TMS and emotion recognition data. Paired samples t tests were performed for post-hoc testing. The alpha level of significance was set at 0.05 (two-tailed) throughout.

Results

Motor corticospinal excitability

Stimulation was well tolerated by all subjects and no side effects were reported. No significant main effect for direction was observed, $F(1, 15) = 0.10$, $p = .76$, whereas a significant main effect was found for emotion $F(2,30) = 3.60$, $p = .04$, $\eta_p^2 = 0.19$ (**Figure 1A**). The two-way interaction between direction and emotion was not significant, $F(2, 30) = 0.23$, $p = .80$. Post-hoc tests show that MEP amplitude was increased independent of direction for anger (mean±SEM z-transformed MEP amplitude: 0.12±0.05) compared with both fear (-0.08±0.05) and neutral (-0.03±0.04), $t(15) = 2.47$, $p = .03$, $d = 0.62$ and $t(15) = 2.14$, $p = .05$, $d = 0.54$ respectively. No difference was observed between fear and neutral expressions, $t(15) = 0.57$, $p = .58$. MEP amplitude differed only from zero for anger, $t(15) = 2.66$, $p = .02$, $d = 0.67$, and not for fear or neutral, $t(15) = -1.70$, $p = .11$ and $t(15) = -0.79$, $p = .44$ respectively.

These effects could not be explained by condition-specific effects on baseline EMG activity, since no main effect of direction, $F(1,15) = 2.04$, $p = .17$, emotion, $F(2, 30) = 1.29$, $p = .28$, or interaction between direction and emotion was found, $F(2, 30) = 2.25$, $p = .15$. Similar results were obtained after controlling for percentage of trials removed (centered), $F(2,28) = 4.62$, $p = .02$, $\eta_p^2 = 0.25$, with an increase in MEP amplitude for anger independent of direction compared with both fear, $p = .007$, and neutral, $p = .05$.

Explicit recognition

A main effect for direction, $F(1, 15) = 34.13$, $p < .001$, $\eta_p^2 = 0.70$ and emotion, $F(2, 30) = 11.51$, $p = .006$, $\eta_p^2 = 0.34$, was found. In addition, an interaction between direction and emotion was observed, $F(2, 30) = 127.12$, $p < .001$, $\eta_p^2 = 0.89$ (**Figure 1B**). Recognition accuracy of angry expressions was higher when directed towards the observer (mean±SEM percentage correct: 89.84±1.88%) compared with away from the observer (38.67±4.16%), $t(15) = 11.56$, $p < .001$, $d = 2.89$. The same pattern was observed for neutral expressions (towards: 87.50±5.71%, and away: 78.91±6.09%), $t(15) = 3.67$, $p = .002$, $d = 0.92$, whereas the opposite was found for fearful expressions (towards: 70.31±3.20%, and away: 94.53±1.12%), $t(15) = 7.77$, $p < .001$, $d = 1.94$. The incongruence effect was most profound for angry expressions (mean±SEM towards – away difference: 51.17±4.43) compared with fearful (24.22±3.12; reversed), $t(15) = 4.83$, $p < .001$, $d = 1.21$, and neutral expressions (8.59±2.34), $t(15) = 9.04$, $p < .001$, $d = 2.26$. The incongruence effect for fearful expression was significant higher compared with neutral expressions, $t(15) = 4.39$, $p = .001$, $d = 1.10$.

Assessment of response patterns in the incongruent conditions showed that when directed away from the observer, anger (mean±SEM percentage of answers: 38.67±4.16%) was more likely to be confused with fear (41.02±4.60%) than with neutral (20.31±3.05), $t(15) = 3.14$, $p = .007$, $d = 0.78$ (**Figure 1C**). No confusion was observed for fear directed towards the observer (70.31±3.20%), with no difference between percentage of anger (12.11±2.77%) and neutral responses (17.59±3.39%), $t(15) = -1.03$, $p = .32$).

In a separate behavioral study ($n = 27$) we replicated the effects on explicit recognition. An interaction between direction and emotion was observed, $F(2, 52) = 139.07$, $p < .001$, $\eta_p^2 = 0.84$, with recognition of angry (towards: 84.49±2.17%, away: 43.06±3.54%, $t(26) = 11.78$, $p < .001$, $d = 2.27$) and fearful expressions (towards: 69.91±2.16%, and away: 92.36±1.98%, $t(26) = 9.31$, $p < .001$, $d = 1.79$) showing opposite results. Anger directed away from the observer was likely to be confused with fear (35.19±3.17%) than with neutral (21.76±2.66), $t(26) = 2.88$, $p = .008$, $d = 0.56$. In this sample, fear directed towards the observer was more likely to be confused with neutral (20.83±2.03%) than with anger (9.26±1.81%), $t(26) = 3.64$, $p = .001$, $d = 0.70$.

Discussion

The goal of the present study was to measure the influence of direction of threat from the perspective of the observer using measures of motor corticospinal excitability and explicit recognition. Interestingly, motor corticospinal excitability levels were independent of direction of anger. However, explicit recognition results showed an incongruence effect for fearful and angry actions. Anger directed towards the observer was recognized better compared to anger directed away from the observer, while the opposite pattern was found for fearful expressions.

The results concur with evolutionary accounts on emotion (Darwin, 1872/2009), and highlight the emotion-action link (Frijda, 1986). The influence of threat can be observed at three interrelated levels in the organism; perception, behavior, and physiology (Panksepp, 1998). Effective threat processing depends on the ability to perceive threat as such, and the consequent physiological changes that eventually would lead to adaptive behavior. Threats in the environment lead to a cascade of reactions in the observer, preparing possible behavioral

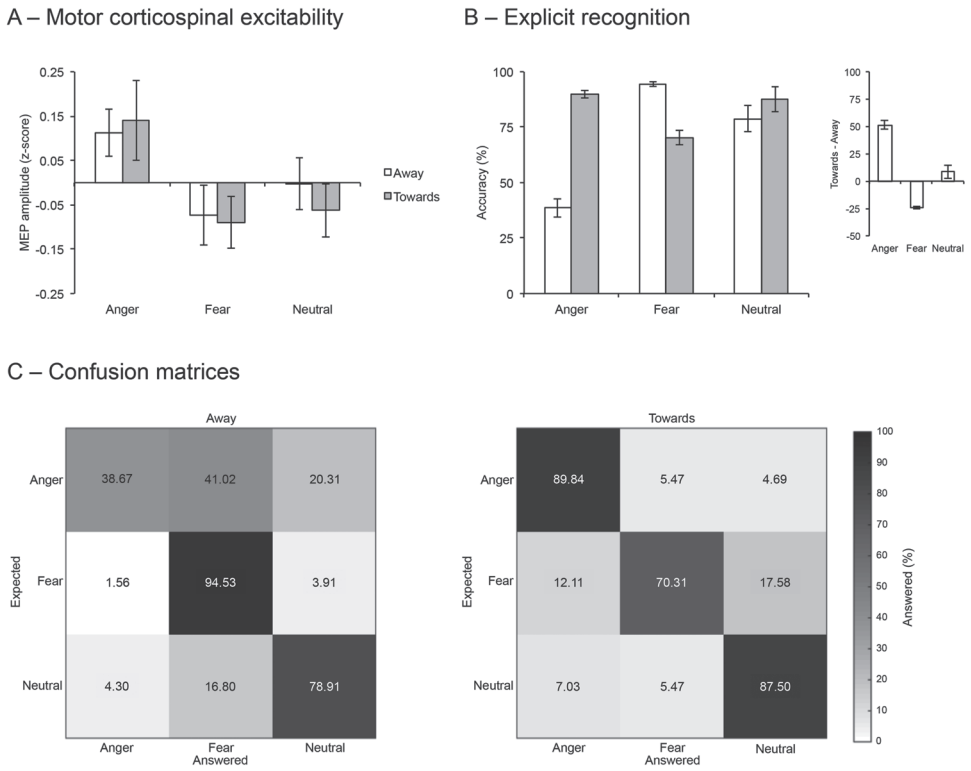


Figure 1. The effect of direction of threat on motor corticospinal excitability levels and explicit recognition accuracy. MEP amplitude did increase for anger independent of direction (A). Recognition accuracy was higher for angry expressions directed towards the observer, and fear expressions directed away from the observers (B). Inset shows the incongruence effect. Anger directed away was confused with fear, while no clear confusion was observed for fearful expressions (C).

consequences (Frijda, 2010), such as startle responses (Lang, Bradley, & Cuthbert, 1990), fast facial reactions (Dimberg & Thunberg, 1998), and changes in heart rate (F. K. Graham & Clifton, 1966). What mechanism and neural network underlie these initial reactions?

The dynamic dual route perspective of affective perception suggests that one route underlies early emotion processing that results in reflexive action, while a cortical-based network underlies recognition and action representation and leads to voluntary behavior (de Gelder et al., 2012). Importantly, a network consisting of the periaqueductal gray, hypothalamus, amygdala, the premotor cortex and pre-supplementary motor area mediates behavioral reactions of the individual when confronted with a threatening situation (de Gelder et al., 2004; Grèzes et al., 2007; Grèzes, Adenis, Pouga, & Armony, 2013a; Grosbras & Paus, 2006; Pichon et al., 2008; 2009; 2012). Directly comparing the neural network underlying perception of fear and angry bodily expressions, Pichon, de Gelder & Grèzes (2009) found that angry expressions activated a wider range of regions such as the premotor cortex. This result fits with our observations in the present study. The confrontation with a conspecific displaying anger could directly activate a reflexive mechanism in the observer. Similar to that in monkeys (for example Avendaño et al., 1983) a direct amygdala-motor network has recently been found in humans (Grèzes et al., 2014). This network would allow for relatively direct activation of the motor system without top-down influences in the face of threat. This view is in agreement with the activation of this network independent of relevance of (Grèzes, Adenis, Pouga, & Armony, 2013a) and attention to (Pichon et al., 2012) angry bodily expressions.

Preparation for defensive reactions not only needs to be relatively independent of attention and other cognitive processes, but it needs to be early and fast as well. Based on previous research (Oliveri et al., 2003; Schutter et al., 2008b), we stimulated the motor cortex 300ms post-stimulus onset and found a selective increase for angry bodily expressions. Interestingly, Borgomaneri, Gazzola & Avenanti (2014a) showed that at 150ms post-stimulus onset, motor corticospinal excitability increased only for stimuli negative in valence, while at 300ms post-stimulus onset, it increased for both stimuli negative and positive in valence (Baumgartner et al., 2007; see also Borgomaneri et al., 2012; Borgomaneri, Vitale, Gazzola, & Avenanti, 2015b; Coombes et al., 2009; Hajcak et al., 2007). In contrast, Schutter, Hofman and van Honk (2008b) found that fearful, but not happy or neutral faces increased motor corticospinal excitability as measured at 300ms after stimulus onset. So far, the temporal dynamics of the influence of emotional signals on motor corticospinal excitability remains elusive.

The observation of no effect of fearful bodily expressions towards or away the observer on motor corticospinal excitability levels, is not necessary in contradiction with a previous study showing a selective increase for static fearful facial expressions (Schutter et al., 2008b). Next to differences in terms of communicative value and immediacy between faces and bodies (de Gelder, 2009), static versus dynamic emotional signals (Grèzes et al., 2007), proximate

versus distal threat (Mobbs et al., 2007), contextual differences in relevance and threat value (Mobbs et al., 2010), could explain the difference in results. In the present study, angry bodily expressions could have had the highest relevance to the participant and the highest threat value compared to fearful and neutral expressions. In the previous study by Schutter and colleagues (2008b), but also in other studies using bodily expressions (Borgomaneri et al., 2012; 2015b; Borgomaneri, Gazzola, & Avenanti, 2014b; Borgomaneri, Vitale, & Avenanti, 2015a) fear was the emotional signal with the most relevance and threat value compared to happy and neutral signals. In other words, anger stands out more in the present study, while fear stands out in the previous study. To counteract potential and unwanted effects of relevance and threat value, future studies should carefully consider which emotional signals to include and compare among. For example, by directly comparing signals of fear and anger (Pichon et al., 2009; 2012).

An additional question is at what moment in time information of direction, relevance and other contextual factors are combined. Early contextual effects (115- 160ms post-stimulus onset) on the processing of emotion signals have been reported (Meeren, van Heijnsbergen, & de Gelder, 2005; Righart & de Gelder, 2008a). Interestingly, a recent study that combined EEG and fMRI, showed that while processing in the amygdala of emotional content was independent of gaze and gesture, these factors are integrated at the level of the premotor cortex already 200ms after stimulus onset (Conty et al., 2012). In contrast, our results show that direction of anger is not affecting motor corticospinal excitability when stimulating at 300ms post-stimulus onset. Again the two dual routes already mentioned could underlie this difference. Angry bodily expressions trigger activation of the first network, which is independent of direction, and result in activation of preparatory processes. It is important to note that these two networks do not necessarily have to be exclusive in terms of brain regions. The crucial distinction is that in one network contextual information is taken into account, while in the other, it is not. The present results of increased motor corticospinal excitability even if the angry person is jumping away from you, might also reflect aberrant activation of preparatory responses. It is possible that top-down influences might counteract this initial process. These questions warrant further testing by probing the primary motor context at different time points.

The pattern of results found for explicit emotion recognition suggests that activation in the second network could underlie these results, as explicit recognition presumably uses different processing resources than the reactive aspect (for example de Gelder et al., 2012). Explicit processing may tap into more cognitive-related processes. It takes the form of categorization (e.g., is it an angry, fearful or neutral person? How angry is the person?), instead of a binary response (e.g., threat or no-threat? Is this something that I need to act upon?). In line with previous modulation by relevance (Grèzes, Adenis, Pouga, & Armony, 2013a), activation in regions of this network reflects the direction of threat. During explicit recognition and categorization of bodily expressions, the direction of the movement in reference to the

observer is taken into account. The explicit recognition results are in line with a prototypical, but context-dependent, distinction between approach and avoidance tendencies and anger and fear. From the perspective of the individual expressing the behavior, anger can be viewed as a manifestation of approach-related behaviors, while fear can be viewed as a manifestation of avoidance-related behaviors (Carver & Harmon-Jones, 2009; Harmon-Jones, 2003; Krieglmeyer & Deutsch, 2013; Wilkowski & Meier, 2010). This division might also be apparent at the perceptual level. Participants perceiving the emotional signal might be more inclined to respond with the label fear if an emotional movement is directed away from them and the label anger if the emotional movement is directed towards them. Indeed, categorization of angry facial expression is facilitated when accompanied by an approach movement (Adams, Ambady, Macrae, & Kleck, 2006) and approach-related movements are faster for angry facial expressions (Wilkowski & Meier, 2010). Importantly, as suggested by the present experiment these effects are dependent on the context. For example, only when approach was linked to aggression did anger enhance approach movements (Krieglmeyer & Deutsch, 2013).

Of importance for future research are personality and other individual differences in the processing of threat in contextual settings. For example, violent offenders are more influenced by an irrelevant angry bodily expression when recognizing happy faces (Kret & de Gelder, 2013). Interestingly, people with a history of exposure to violent crimes compared to people with no history showed increased reaction times to threat directed towards them (Fernandes et al., 2013). Incorporating the perceptual and personality domain, a recent TMS study showed that interhemispheric connectivity was related to an attentional bias to angry facial expressions and to an aggressive personality style (Hofman & Schutter, 2009). As effects of personality on motor corticospinal excitability levels have also been reported (Wassermann, Greenberg, Nguyen, & Murphy, 2001), future studies may incorporate measures of aggression- and/or anxiety-related traits in the study of perception and interpretation of threat and the occurrence of defensive and/or aggressive behavior.

In conclusion, the present study showed that the direction of threat influenced motor corticospinal excitability and explicit recognition differently. Importantly, motor corticospinal excitability increased independent of direction of anger, while explicit recognition was directly related to the direction of the emotional signal. This suggests that in the face of threat, a rapid mechanism is activated to cope with the incoming threat that is independent of explicit recognition.

Chapter 3

Trait dominance promotes reflexive staring at masked angry body postures

This chapter is published as:
Hortensius R, van Honk J, de Gelder B & Terburg D (2014). Trait dominance promotes reflexive staring at masked angry body postures. *PLoS ONE*, 9:e116232.

Abstract

It has been shown that dominant individuals sustain eye-contact when non-consciously confronted with angry faces, suggesting reflexive mechanisms underlying dominance behaviors. However, dominance and submission can be conveyed and provoked by means of not only facial but also bodily features. So far few studies have investigated the interplay of body postures with personality traits and behavior, despite the biological relevance and ecological validity of these postures. Here we investigate whether non-conscious exposure to bodily expressions of anger evokes reflex-like dominance behavior. In an interactive eye-tracking experiment thirty-two participants completed three social dominance tasks with angry, happy and neutral facial, bodily and face and body compound expressions that were masked from consciousness. We confirmed our predictions of slower gaze-aversion from both non-conscious bodily and compound expressions of anger compared to happiness in high dominant individuals. Results from a follow-up experiment suggest that the dominance behavior triggered by exposure to bodily anger occurs with basic detection of the category, but not recognition of the emotional content. Together these results suggest that dominant staring behavior is reflexively driven by non-conscious perception of the emotional content and triggered by not only facial but also bodily expression of anger.

Introduction

> A proud man exhibits his sense of superiority over others by holding his head and body erect. He is haughty (haut), or high, and makes himself appear as large as possible; so that metaphorically he is said to be swollen or puffed up with pride
>
> – Darwin, 1872/2009 p. 142

Social dominance is often established and maintained through direct gaze and sustained eye-contact. The mechanism underlying such staring-contest behavior is fundamental to the establishment of social hierarchies and is found in humans and other primates (Mazur & Booth, 1998; Terburg, Hooiveld, Aarts, Kenemans, & van Honk, 2011). Dominance and submission are, however, not exclusively conveyed or provoked through facial features. One only has to imagine the figure of an approaching person in a dark alley to appreciate that body language might be an important factor in dominance-submission interactions. Indeed, briefly adopting a high-power pose may lead to dominance-related changes such as increased testosterone and decreased cortisol levels, heightened risk-taking, and increased feelings of power (Carney, Cuddy, & Yap, 2010). In the observer, the perception of a threatening bodily expression can subsequently trigger neural mechanisms underlying automatic defensive action (de Gelder et al., 2004; Pichon et al., 2012).

The relation between sustained eye-contact and personality traits of dominance resembles a non-conscious reflex-like mechanism (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a). Despite the ecological validity and biological relevance of body postures (de Gelder, 2009), surprisingly few studies have been conducted on their interplay with personality traits and behavior. Here we aim to fill this gap by investigating whether angry bodily expressions that are not perceived consciously evoke reflex-like dominance behavior similar to the staring-contest as was shown previously with slower gaze-aversion from angry compared to happy faces (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a). Given the strong link between aggression and dominance (Mazur & Booth, 1998), and the notion that physical aggression is acted out with the body, we expect that these gaze-aversion effects will generalize to bodily dominance-cues.

Social Dominance Experiment

Methods

Participants

Thirty-two healthy individuals (sixteen females), aged between 19 and 26 years, participated in exchange for course credit or eight Euros. The study received approval from the internal faculty board (Human Biopsychology and Psychopharmacology) at Utrecht University. Participants were unaware of the aim of the study, and provided written informed consent. The research was conducted according to the principles expressed in the Declaration of Helsinki.

Stimuli and tasks

The same angry, happy and neutral facial expressions (five male, five female actors) from (Ekman & Friesen, 1976) were used as in Terburg et al. (2011; 2012a). A mask was made from cut-up and randomly reassembled faces. Angry, happy and neutral bodily expressions (five male, five female actors) were taken from the Tilburg Stimulus Set (van de Riet, Grèzes, & de Gelder, 2009). The neutral control expression was an instrumental action (cf. making a telephone call). All three expressions were well recognized in a separate group of students (n = 24; mean±sd percentage correct for angry: 91.30±2.29, happy: 98.26±0.81, neutral: 97.39±1.57). In addition to the isolated facial and bodily expressions, we tested if the effects were generalizable to full emotional expressions including facial and bodily signals. Therefore we constructed face-body compounds (Meeren et al., 2005) by combining these expressions (**Figure 1**). Using Photoshop CS2 (Adobe Systems Inc., San Jose, CA, USA) faces from the MacBrain Face Stimulus Set were carefully resized and positioned on top of the body using realistic proportions (face-body ratio of 1:7). Contrast and brightness of the face was adjusted to match the values of the body. Only congruent compounds were created (e.g. angry face with angry body). The mask for bodily and compound expressions consisted of a scrambled image of all stimuli combined.

We used a procedure similar to Terburg and colleagues (2011). Participants performed three eye-tracking tasks with faces, bodies or face-body compounds as target stimuli. Face-only and body-only tasks were tested first (counterbalanced across participants). The compound task was presented last to prevent the more complex stimuli from interfering with their simpler counterparts due to repetition effects. In each trial a gray pre-mask with a central fixation-cross (random interval between 1000–1500 ms) preceded a red, green or blue emotional target-stimulus (angry, happy or neutral), followed by a post-mask of similar luminance and color. In order to prevent habituation to the masking, different versions of the masks were used. We selected a target presentation time of 14ms (van Honk, Peper, & Schutter, 2005), because the previously reported effects of trait dominance on gaze-aversion were observed exclusively in individuals that were fully unaware of the masked facial emotions (Terburg et

Figure 1. Examples of an angry, happy and neutral face-body compound expressions.

al., 2011) and bodily expressions are confidently detectable at presentation durations of 33ms (Stienen & de Gelder, 2011).

Participants' task was to avert gaze as fast as possible to one of three circles below the stimulus with the same color (**Figure 2A**). The emotional expressions were presented in a fixed sequence, repeated five times (NxxyNyyxNNyyxNxxyN; N = neutral; x and y = angry or happy counterbalanced over participants), in order to ensure that all successive trial-types occurred equally often (Terburg, Aarts, & van Honk, 2012a). Before the onset of each task, participants performed 10 neutral practice trials. Stimuli were presented on a 17-inch CRT monitor. The session was concluded with three 30-trial awareness checks, with the stimuli presented in the same manner as the social dominance task, but with the instruction to identify the emotion of the masked target in a 3-alternative-forced choice design (3AFC).

Trait dominance

Participants completed the Behavioral Activation Scale (BAS) (Carver & White, 1994), as a measure of trait dominance and non-dominance related reward sensitivity. The BAS questionnaire consists of three subscales: fun-seeking (BASF; e.g., "I will often do things for no other reason than that they might be fun"), drive (BASD; e.g. "I go out of my way to get things I want"), and reward responsiveness (BASR; e.g. "It would excite me to win a contest"). These subscales have successfully been used to distinguish between dominance (BASD and BASR) and non-dominance related reward sensitivity (BASF) (Carver & White, 1994; Terburg et al., 2011).

Data analysis.

Gaze latencies (time between target onset and first gaze on target-circle) were recorded with a

Tobii X120 binocular eyetracker sampling at 120 Hz (Tobii Technology, Danderyd, Sweden). Latencies shorter than 100ms or more than 3SDs from the individual's mean within each task were discarded, and mean latency was computed for each emotional condition in each task, and used for further analysis.

Dominance-related BAS scores were calculated by combining the scores on the drive and reward-responsiveness BAS scale, $r_s(32) = .67$, $p<.001$ (Terburg et al., 2011). Non-dominance related BAS scores were defined as the score on the fun-seeking BAS scale. Dominance and non-dominance related BAS scores were not significantly related, $r_s(32) = .13$, $p = .48$.

Individuals who scored significantly above chance-level (>14 correct; chance level = 10 correct on 30 trials; binomial test with one-tailed $\alpha = .05$) on the objective awareness-check were excluded from further analyses (face: null, body: three, compound: five). Using a general linear model (GLM) for repeated measurements, we tested for each task separately if emotional expression influenced gaze duration. In line with previous studies (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a), linear regression analyses were used for the three tasks separately on the angry-happy contrast with dominance and non-dominance related BAS-scores as predictor variables.

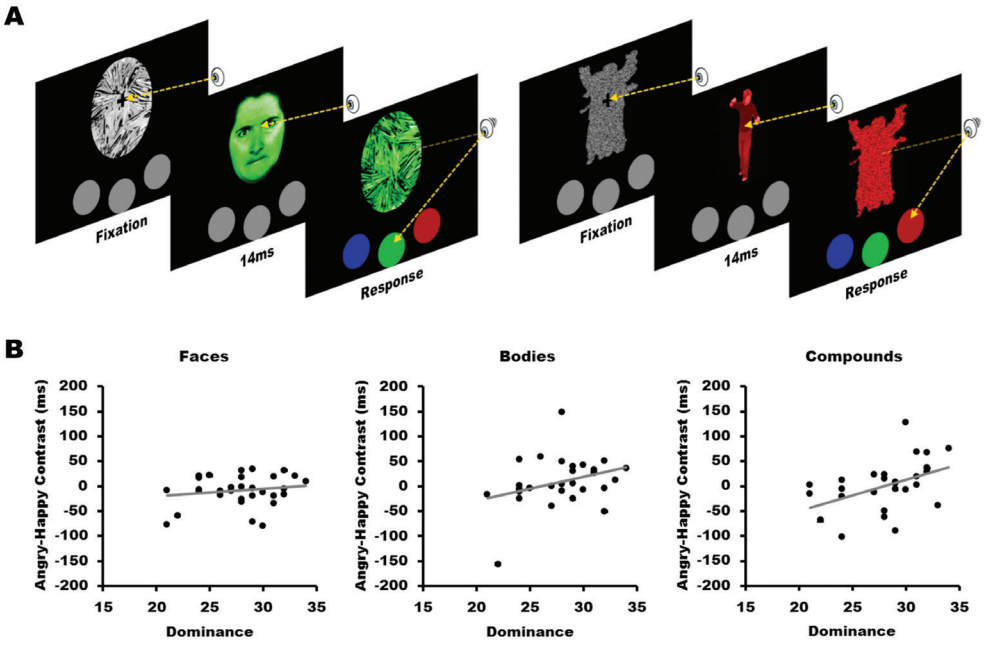


Figure 2. Illustration of the social dominance task and results. Outline of the social dominance task (A). Dominance increases gaze duration to angry bodily and compound expressions, but not to facial expressions (B). Part A is adapted from Terburg et al. (2011).

Results

No main effect of emotion was found for facial, $F(2,62) = 1.00$, $p = .37$, bodily, $F(2,56) = 1.31$, $p = .28$, or compound expressions, $F(2,52) = 0.02$, $p = .98$. Significant regression models were observed for bodily, $F(2,26) = 9.16$, $p = .001$, $R^2 = .41$, and compound, $F(2,24) = 3.47$, $p = .05$, $R^2 = .22$, but not for facial, $F(2,29) = 1.11$, $p = .35$, $R^2 = .07$, expressions. Consistent with our predictions, slower gaze-aversion from angry compared to happy bodily expressions was positively related to dominance traits ($\beta = .48$, $p = .005$) and negatively to non-dominance related reward sensitivity ($\beta = -.57$, $p = .001$; **Figure 2B**). These results were similar when two individuals with bias scores >±150ms were removed, $F(2,24) = 9.39$, $p = .001$, $R^2 = .44$, with dominance traits ($\beta = .40$, $p = .02$) and non-dominance related reward sensitivity ($\beta = -.65$, $p<.001$) as predictors. Dominance traits also positively predicted gaze-aversion from angry compared to happy compound expressions ($\beta = .44$, $p = .02$), but non-dominance related reward sensitivity did not contribute significantly to this model ($\beta = .15$, $p = .40$).

Discussion

As hypothesized, we observed slower gaze-aversion from non-conscious angry compared to happy body postures in relation to dominance traits. This effect was similar for body and compound stimuli and is in line with previous studies using face stimuli presented at a longer stimulus duration (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a). This suggests a robust effect of body-evoked dominance behavior. However, in the present study we did not observe the same effect with face stimuli. Importantly, the present and previous (Terburg et al., 2011) study were similar except for presentation duration of the target stimuli. In the previous study the faces were presented for 33ms and the dominance effect was exclusively found in the participants, about two-thirds of the sample, that were fully unaware of the emotional content of the stimuli (Terburg et al., 2011). Crucially, although faces (but in general not their emotional expression) are detectable at 33ms, they are fully undetectable at 14ms (Williams et al., 2004). Body postures, but again not their emotional expression, might have been detected at such short durations. Therefore, we cannot exclude that the reflexive dominance behavior we observe in our experiments depends on some form of basic detection of the stimuli. We therefore tested the hypothesis that at 14ms presentation duration bodies are detectable, but faces are not.

Control Experiments

Methods

Participants
Twenty healthy individuals (ten females) aged between 18 and 24 years participated in exchange for course credit. The participants did not take part in the social dominance experiment and were unaware of the aim of the study.

Stimuli and tasks
Participants performed eight short experiments in which they had to detect the occurrence of a target-stimulus (detection task) or recognize the target-emotion (emotion recognition task). We used four different stimulus durations (10/14/20/28 ms). Refresh rate of the CRT monitor was adjusted with respect to the duration of the stimulus (i.e. for a stimulus duration of 10 and 20ms the refresh rate was changed to 100 Hz). Duration and target-stimulus were counterbalanced across participants. The same stimuli and trial procedure were used as in the social dominance task. Either faces or bodies served as target-stimuli. In each trial a gray pre-mask preceded a colored target-stimulus (happy, angry, or neutral expression), which was followed by a post-mask of similar color, shown until response. In the detection task participants indicated if they had seen the target-stimulus (yes/no), while in the emotion recognition task the participants indicated the emotion. In the detection task 50% of the trials contained no stimulus. For each condition twelve trials were shown, with a total of 576 trials in the detection task and 288 trials in the emotion recognition task.

Data analysis
For the detection task we calculated the d-prime (d'), which measures the distance between signal and noise (D. M. Green & Swetz, 1966). With a d' of 0 the individual cannot discriminate between signal and noise, whereas a d' of 1 suggests medium performance and a d' of 4.65 suggests optimal performance. The d' is calculated with the following formula:

$$d' = \Phi^{-1}(H') - \Phi^{-1}(FA')$$

We used the formula proposed by Snodgrass and Corwin (1988) to calculate corrected hit rate (H') and corrected false alarm rate (FA') out of the hits (h), correct rejections (cr), misses (m) and false alarms (f):

$$H' = (h + 0.5) / (h + m + 1)$$

$$FA' = (f + 0.5) / (f + cr + 1)$$

To test differences in detection (d') between facial and bodily expressions at different stimulus

durations, a general linear model (GLM) for repeated measurements with stimulus-type (2) and duration (4) as within subject factors was used. A similar approach was used for emotion recognition (number of trials correct). In addition, we tested if emotion recognition for each target-stimulus was significantly different from chance level at each duration (36 trials in total per target-stimulus per duration, chance level = 12) by means of one sample t-test. Post-hoc paired samples t tests were Bonferroni-corrected.

Results

Detection

A main effect of type of stimulus was found, $F(1,19) = 17.82$, $p<.001$, $\eta_p^2 = 0.48$. Post-hoc t-tests showed that the d' for bodies was significantly higher compared to faces at all durations (p's≤.01). Furthermore, the d' for bodies was significantly different from zero at all durations (p's≤.008), whereas the d' for faces was only significant from zero with a duration of 28ms ($p = .04$). A main effect of duration, $F(3,57) = 6.15$, $p = .006$, $\eta_p^2 = 0.25$ was observed. The overall d' at 28ms was significantly higher compared to 14 ms, $t(19) = -3.42$, $p = .02$. No significant interaction between type of stimulus and duration was observed, $F(3,57) = 0.06$, $p = .98$. **Table 1** reports the d' values across conditions.

Emotion recognition

Number of trials correct differed between type of stimulus, $F(1,19) = 5.70$, $p = .03$, $\eta_p^2 = 0.23$. Participants had more trials correct when recognizing bodily (14.01±0.87) compared to facial (11.70±0.26) expressions. Importantly, for both target-stimuli the number of trials correct at each duration was not significantly different from chance-level (12 correct; p's>.22), except for a marginally significant difference for bodies presented at a duration of 14ms ($p = .06$). No main effect of duration was observed, $F(3,57) = 0.26$, $p = .85$. Furthermore, no significant interaction between type of stimulus and duration was found, $F(3, 57) = 0.69$, $p = .56$. **Table 1** reports the number of trials correct across conditions.

Discussion

As expected, with none of the presentation durations were the participants able to recognize the emotional expression of the masked faces or bodies. In contrast, stimulus detection performance was different for faces and bodies. Results showed medium performance for body detection, but detection of faces was only significantly different from zero at a presentation time of 28 ms. The latter result suggests that the faces in the social dominance experiment remained undetected. Moreover, although their emotional expressions were successfully

Table 1. Results for detection and emotional recognition tasks

	10 ms	14 ms	20 ms	28 ms
Detection				
Faces	-0.03±0.06	0.04±0.05	0.16±0.08	0.43±0.15
Bodies	0.98±0.25	1.02±0.28	1.22±0.28	1.47±0.37
Emotion recognition				
Faces	11.90±0.43	11.70±0.42	11.45±0.44	11.75±0.50
Bodies	13.45±0.89	14.15±0.80	14.00±1.03	14.45±1.20

Mean ± standard error d' reported for detection; mean ± standard error number of trials correct reported for emotion recognition.

masked, the bodies in the social dominance experiment, as well as the faces in our previous experiments (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a), were most likely detectable.

General Discussion

In the present study we investigated whether dominant individuals exhibit reflex-like gaze behavior when confronted with bodily anger. In support of our hypothesis we show for both bodies, and compounds, a positive relationship between trait dominance and slower gaze-aversion from non-consciously processed angry compared to happy expressions. The results from the control experiments suggest that the absence of gaze-aversion effects with facial expressions in the present experiment may be related to the fact that faces, but not bodies, are undetectable at presentation times of 14 ms. It is important to note that in the social dominance task using bodies or faces, the stimulus property that varies and therefore needs to be masked is the emotional expression (Van Selst & Merikle, 1993). Given that emotional expressions were successfully masked in the present as well as in previous studies using this task (Terburg et al., 2011; Terburg, Aarts, & van Honk, 2012a), the results point at non-conscious effects of facial (previous study) and bodily (present study) anger on dominance behavior, that is, in the absence of critical awareness of the emotional content (Van Selst & Merikle, 1993).

Bodily expressions signal intentions and actions, and have been suggested to automatically trigger action responses (de Gelder, 2009). They activate subcortical mechanisms (de Gelder et al., 2004; Pichon et al., 2012) associated with early emotional processing and reflexive action (de Gelder et al., 2012). Recent evidence on the combination of dominance traits, electrophysiology, endocrine functions and behavioral responses to facial anger suggests that staring-behavior for dominance is rooted in a relatively increased subcortical over cortical processing mode (Hofman, Terburg, van Wielink, & Schutter, 2013), and mediated by the steroid hormone testosterone (Terburg, Aarts, & van Honk, 2012a) (Terburg & van Honk,

2013). Involvement of testosterone in staring-contests has also been suggested in other primate species (Mazur & Booth, 1998), which underscores the importance and adaptive relevance of this type of dominance behavior (Darwin, 1872/2009). As such, these results provide for the first behavioral evidence that non-conscious bodily anger can evoke ecologically valid, reflex-like dominance behavior.

Interestingly, although we did not observe dominance behavior in relation to facial anger, behavioral effects using the same threshold (14 ms) have previously been found when using fearful faces (van Honk et al., 2005). This intriguing difference might reflect the evolutionary relevance of fear over anger as a signal of predatory danger (Öhman, 2005), but further research is needed to substantiate this claim (Pessoa, Japee, & Ungerleider, 2005). In addition, bodily expressions of anger might bias perception towards adaptive action ('I need to dodge the punch') whereas facial expressions of anger might bias perception towards understanding intention ('why is the person angry at me?') (de Gelder, 2009). Notwithstanding that angry facial expression still trigger reflexive behavior with longer stimulus duration (Terburg et al., 2011), bodily signals of threat might simply be more effective in triggering dominance behavior.

The present and previous results (Terburg et al., 2011) suggest that basic detection, but not recognition, of the emotional content, lies at the foundation of the relation between trait dominance and reflexive staring. Detection and recognition of bodily expressions, but also facial expressions, are possibly mediated by distinct but connected parallel neural routes with different behavioral outcomes (de Gelder et al., 2012; de Gelder & Rouw, 2001). It is important to note that detection and recognition are not necessarily dependent upon each other, i.e. detection can occur without recognition and vice versa. Indeed, a recent study showed that above chance-level emotion categorization of a facial expression may take place when observers cannot reliably categorize the stimulus as either a face or an object (Seirafi, De Weerd, & de Gelder, 2013). An interesting phenomenon in this respect is 'affective blindsight' (AB), which describes patients with cortical blindness who can still process some of the emotional content of visual information (Anders et al., 2004; de Gelder & Hadjikhani, 2006; de Gelder, Vroomen, Pourtois, & Weiskrantz, 1999; Morris, 2001; Pegna, Khateb, Lazeyras, & Seghier, 2005; Tamietto et al., 2009; Van den Stock, Tamietto, Hervais-Adelman, Pegna, & de Gelder, 2015b). It is thought that AB is driven by subcortical brain regions, such as the amygdala, pulvinar, and superior colliculus (Tamietto & de Gelder, 2010; Tamietto, Pullens, de Gelder, Weiskrantz, & Goebel, 2012), which is in line with the above proposed involvement of subcortical areas in reflexive dominance behavior. Furthermore, in line with our results AB patients seem to be able to detect bodies, but not faces, above chance-level (Van den Stock et al., 2015b), whereas the emotional content of both faces and bodies do evoke affective responses (Tamietto et al., 2009). Importantly, these effects are non-conscious in nature and as such might resemble the non-conscious emotional modulation of dominance behavior observed in the present study.

In conclusion, the present study replicates and extends previous research on dominance behavior (Terburg et al., 2011; van Honk & Schutter, 2007) and provides important insights into reflexive social behavior. Exposure to angry bodily expressions can drive reflex-like gaze behavior and this finding provides a new window on the interplay between personality traits and behavioral reflexes.

Chapter 4

The neural mechanisms of threat perception after basolateral amygdala damage

This chapter is under review as:
Hortensius R, Terburg D, Morgan B, Stein DJ, van Honk J & de Gelder B. The neural mechanisms of threat perception after basolateral amygdala damage.

Abstract

The amygdala plays an important role in the processing of threat signals, but it has so far been difficult to investigate the contribution from the different amygdala nuclei in humans. The current study investigated the neural signature of basolateral amygdala damage during perception of facial and task-irrelevant bodily threat signals. Five individuals with Urbach-Wiethe disease with focal basolateral amygdala damage and twelve matched controls viewed facial and bodily expressions presented in congruent and incongruent face-body compounds while attention was always directed at the facial expression. Results showed that activation for fearful versus happy bodies was increased in the inferior parietal lobule in the Urbach-Wiethe disease group compared to controls. Moreover, after basolateral amygdala damage ambiguous threat processing is related to decreased activation in the temporal pole, but increased activity in the ventral and dorsal medial prefrontal and medial orbitofrontal cortex. This division between the prefrontal- and temporal-network was also present in the functional connectivity maps. Decreased temporal pole activity and increased prefrontal activity may underlie a switch from resolving ambiguity to dysfunctional threat signaling and regulation, resulting in hypersensitivity to threat after basolateral amygdala damage.

Introduction

The face and body are ubiquitous social and emotional signaling systems. Recognizing these face and body signals, especially in the case of potential threat, is of crucial importance for adaptive reactions to the other person. Previous studies have reported that the amygdaloid complex is a key region for recognition of these signals. Studies using neuroimaging in healthy individuals have shown that the amygdala (AMG) is activated in seeing facial expressions (Morris et al., 1996; see Sabatinelli et al., 2011 for a review) as well as bodily expressions (see de Gelder et al., 2012 for a review; Hadjikhani & de Gelder, 2003). The role of the AMG spans a wide range of mechanisms related to threat recognition, including on the perception side, rapid detection the visual stimulus, and on the behavior side, automatic reflexive behavior and deliberate action. Presumably, each of these is supported by partly different networks involving the AMG in connection with other key structures.

To better understand the role of the AMG in threat perception we need to distinguish the role of its different nuclei and their connectivity profile. The major division of the AMG is between the superficial (SFA), basolateral (BLA), and central-medial amygdala (CMA) (McDonald, 1998). This subdivision correspondents to three different networks, the olfactory network (mediated by the SFA), the autonomic network (CMA), and the frontal-temporal network (BLA) (Bzdok, Laird, Zilles, Fox, & Eickhoff, 2013; Swanson & Petrovich, 1998). The latter two networks are of importance for the processing of and reactions to threat. The CMA mediates reflexive reactions to threat together with the hypothalamus and brainstem (A. S. Fox, Oler, Tromp, Fudge, & Kalin, 2015; Mosher, Zimmerman, & Gothard, 2010). The role of the BLA in threat perception and reaction is more complex and diverse. The BLA receives input from the sensory thalamus and sensory cortices, and it has bidirectional connections with many cortical, including frontal and temporal, regions such as the ventral and dorsal part of medial prefrontal cortex (MPFC) and temporal pole (TP) (H. T. Ghashghaei & Barbas, 2002; Heimer, Harlan, Alheid, Garcia, & de Olmos, 1997). The BLA-temporal network presumably plays a role in the emotional labeling of an object category and determining its affective value (Benarroch, 2015). The connections with the medial and orbital prefrontal cortex have been implicated in safety signaling, emotion regulation and affective learning (Likhtik & Paz, 2015).

It has so far been difficult to directly investigate the functional contribution of different AMG nuclei and associated neural networks in humans during threat perception. Urbach-Wiethe disease (UWD) is a disease that in some cases leads to bilateral calcification of the AMG. Detailed investigation in five individuals with UWD from the South African Northern Cape revealed that the calcification of the basolateral amygdala was associated with a lower threshold for fear recognition and a stronger task interference from non-conscious perceived fearful faces (Terburg, Morgan, Montoya, Hooge, et al., 2012b). A recent study with three individuals from the same group showed a hypersensitivity to bodily threat signals as indexed by a higher influence of unattended threat body expressions on recognition of the facial

emotion (de Gelder et al., 2014). The neural mechanisms underlying these behavioral consequences of BLA damage have however not been studied yet.

Here, we mapped the neurofunctional signature of perception of facial and bodily expressions in isolation (happy and fear), and in congruent and incongruent face-body compounds in five participants with BLA calcification and twelve matched controls. It can be hypothesized that the BLA-frontal and BLA-temporal network are differentially targeted by BLA damage with each having distinct behavioral consequences. First, the BLA has an inhibitory influence on the MPFC (Dilgen, Tejeda, & O'Donnell, 2013) and damage to the BLA would result in an increase in activation in both the dorsal and ventral part of the MPFC. If the previously published behavioral bias is a result of hypersensitivity to threat we would expect increased activation in this BLA-frontal network and possibly motor-regions due to aberrant action preparation that accompanies this hypersensitivity. If on the other hand the bias is due to hypersensitivity to ambiguity, increased activity should be found in the BLA-temporal network due to emotion interpretation deficits, that is gating valence of face and body stimuli and/or decreased ambiguity resolution.

Materials and Methods

Participants

Five volunteers with UWD disease from the Northern Cape of South-Africa (Thornton et al., 2008) and 12 matched controls from the same region participated in the present experiment. Participants had no history of secondary psychopathology or epileptic insults. Environmental conditions, age, and neuropsychological characteristics were similar for UWD and control participants (**Supplementary Table 1**). Previously, structural and functional MRI assessment by means of cytoarchitectonic-probability labeling provided evidence that the calcification is restricted to the BLA (Klumpers, Morgan, Terburg, Stein, & van Honk, 2014b; Terburg, Morgan, Montoya, Hooge, et al., 2012b). **Figure 1** shows the location and size of the calcification and a three-dimensional reconstruction of the lesion. Three of the five UWD participants (UWD 1-3) also participated in the previously reported behavioral experiment (de Gelder et al., 2014). Participants were unaware of the aim of the study and provided written informed consent. The study was approved by the Health Sciences Faculty Human Research Ethics Committee of the University of Cape Town and carried out in accordance with the standards set by the Declaration of Helsinki.

Stimuli and Task

Fearful and happy faces (MacBrain Face Stimulus Set) were paired with a fearful or happy body (de Gelder & Van den Stock, 2011), resulting in congruent (e.g., a fearful face with a fearful body) or incongruent (e.g., a happy face with a fearful body) compounds (Meeren et

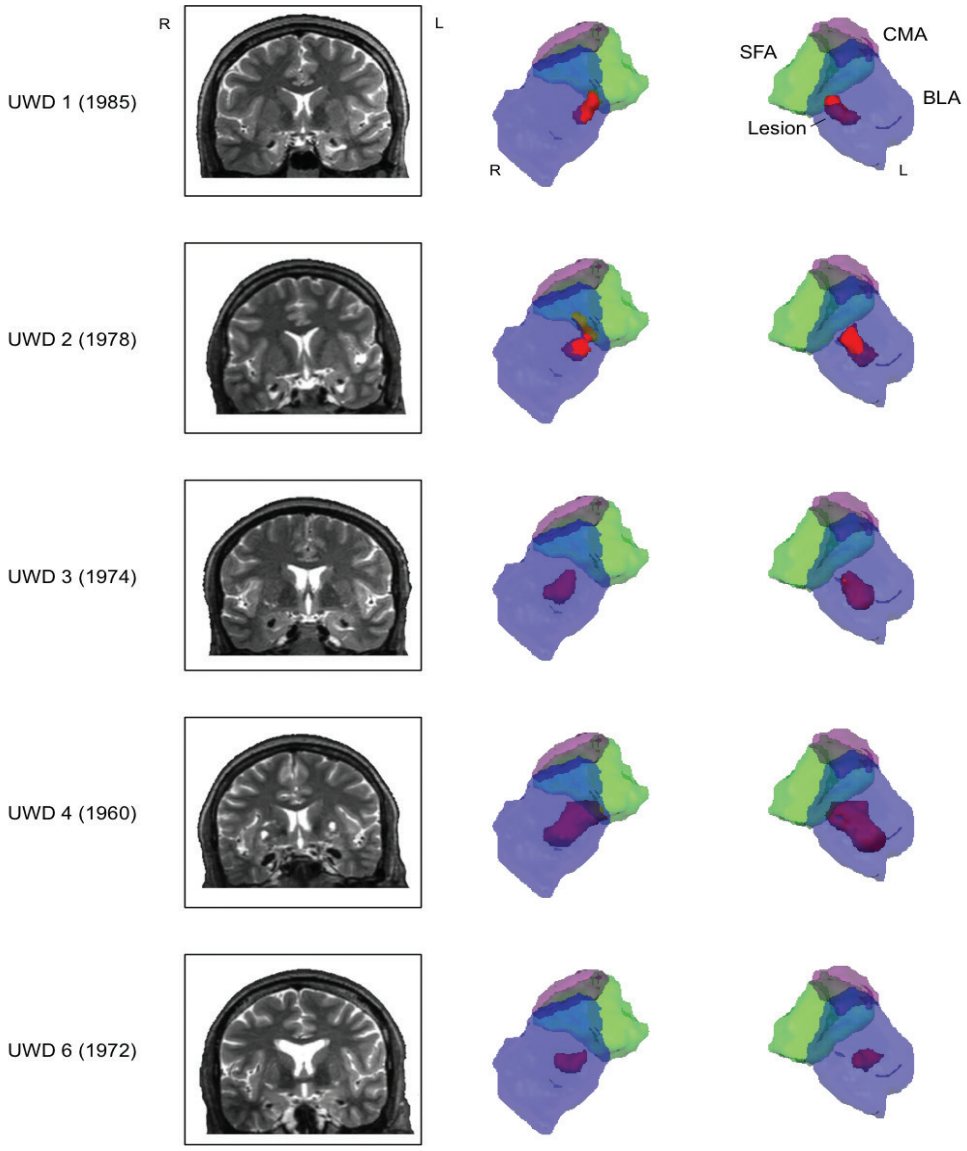


Figure 1. Location and size of the BLA damage. Coronal view of T2-weighted magnetic resonance images (left) and three-dimensional reconstruction (right) of the lesion for the five Urbach-Wiethe disease (UWD) participants with birth year indicated. Reconstruction of the AMG subnuclei was based on the cytoarchitectonic probability maps from Amunts et al. (2005) in Eickhoff et al. (2005).

al., 2005). Control stimuli were created in which the face or body or both were replaced with a grey shape (e.g., a happy face with grey rectangle, a grey oval with a fearful body, grey oval and grey rectangle). Ten unique stimuli (5 female) per condition were created. **Figure 2** presents examples of the stimuli used.

Participants were instructed to focus on the face only and not to pay attention to the rest of the body. In order to maintain this focus a fixation cross was placed on the nose of the face-body compound stimulus. Participants performed a passive oddball task (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). During the course of the experiment the fixation cross could change into a red circle. Participants were instructed to pay attention to this change but did not have to make an overt response. This was done to counteract any possible contamination by a motor response in the trials of interest. A nurse familiar to the participants was trained to provide instructions for the task outside of the scanner. The task was explained to the participant with examples of face-body compound stimuli not used in the actual experiment. The experiment started when participants indicated that they understood the instructions.

The experiment used a block design. During a stimulation block the 10 stimuli belonging to the same category (e.g., fearful face with a happy body) were presented in a random order for 800ms each, with an inter stimulus interval of 200ms (total duration 10 s). Each run consisted of 27 stimulation blocks (9 different conditions repeated 3 times) and 6 oddball blocks presented in a random order. This was followed by an inter block interval of 6 s. Three rest blocks of 10s each were presented at a fixed time point (after stimulation/oddball block 5, 11, and 22). During these rest blocks no stimuli were shown, to counteract any possible habituation and provide a more dynamic presentation. Participants completed two runs, with a total time of 18 minutes. Stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, USA), projected onto a screen located at the end of the scanner bore. Each new event was synchronous with a new scan volume.

Image acquisition

Data was acquired with a Siemens Magnetom Allegra 3 Tesla head-only scanner (Siemens Medical Systems GmBH, Erlangen, Germany) at the Cape Universities Brain Imaging Centre (CUBIC) in Cape Town, South Africa. Earplugs attenuated the scanner noise and padding was used to reduce head movements. Functional whole brain coverage was achieved using 2D echo-planar images sequence. Each volume contained 36 slices acquired in ascending order with a 3.5 mm isotropic resolution (interslice gap = 0.525, TR = 2000ms, TE = 27 ms, flip angle = 70°, field of view (FOV) = 225 x 225 mm^2, matrix size = 64 x 64). In total 278 functional volumes were collected per run. After the final functional run a high-resolution T1-weighted anatomical scan with 1 mm isotropic resolution was collected (no gap, TR = 2300ms and TE = 39 ms, FA = 9°, field of view = 240 x 256 mm^2, matrix size = 256 x 256).

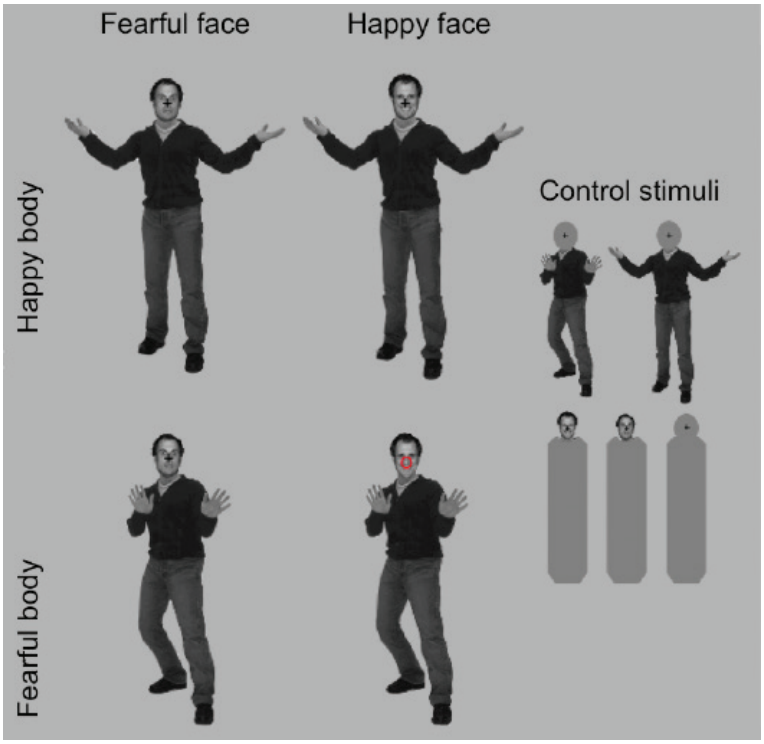


Figure 2. Examples of stimuli used in the experiment.

functional Magnetic Resonance Imaging preprocessing and analyses

Data preprocessing and analyses were carried out using BrainVoyager QX Version 2.8.4 (Brain Innovation, The Netherlands, www.brainvoyager.com). The first 4 volumes of each run were discarded to avoid T1 saturation effects. Preprocessing of the functional data consisted of slice time correction (using sinc interpolation), a rigid-body algorithm to correct for small movements between scan (trilinear/sinc estimation and interpolation), and temporal high-pass filtering (GLM-Fourier with two cycles sine/cosine per run including linear trend removal). No spatial smoothing was used. Functional data was co-registered to the anatomical data, and all data was normalized into Talairach space.

To reduce individual macro-anatomical differences between participants and crucially between the UWD and control group, and to subsequently improve statistical power, Cortex-Based alignment was used (Frost & Goebel, 2012; Goebel, Esposito, & Formisano, 2006). This high-resolution cortical mapping procedure achieves a non-rigid alignment of different brains using the individual curvature information that reflects the gyri and sulci folding pattern (see Frost and Goebel, 2012 for more details). As the CBA procedure already applies smoothing to the data and results in superior alignment between participants, no further spatial smoothing was used. Pre- and post-CBA comparison of between-subjects alignment is shown in **Supplementary Figure 1**.

At the single-subject level, fixed-effects whole-brain general linear model were performed using a regression model with each condition and oddball block defined as predictors. The z-transformed motion predictors were included as predictors of no interest. In addition, to reduce error variance possible, outlier predictors were included in the model. An outlier map was created for each run to show clusters that have a time course value of > 6SD above the mean. These maps were manually inspected for outlier clusters and if the value was > 6SD above the mean, but not related to motion or an incidental spike, the time course was extracted, z-transformed, and included in the design matrix. Next, the design matrix of each run of each participant was checked for shared variance to prevent over fitting. If a predictor was explained by the combination of other predictors ($R^2 > .80$), it was removed from the design matrix. Thus, besides the task predictors (9 + 1 oddball), motion predictors and possible outlier predictors were included in the design matrix. The number of predictors of no interest ranged between 5 and 9 and did not differ between groups, p's > .22.

At the group level a random-effects general linear model was performed. Using a dummy-coded general linear model the following analyses were performed:

1. We first investigated the regions that were activated for fearful compared to happy bodies regardless of the facial information and vice versa.

2. To map the effect of incongruent versus congruent face-body compounds we contrasted incongruent (fearful face and a happy body, and happy face and a fearful body) with congruent (fearful face and a fearful body, and happy face and a happy body).

3. To determine the influence of unattended fear versus unattended happiness, fearful bodies with a happy face or grey oval were contrasted with happy bodies with fearful face or grey oval.

Between-group as well as within-group maps (for UWDs and controls separately as well as combined) were calculated. Additional analyses are reported in the **Supplementary Material**. The between-group maps were cluster size corrected (Forman et al., 1995). In brief, a whole-brain correction was calculated by estimating a false-positive rate for each cluster by taking into account the spatial smoothness of the initial statistical map. In accordance with Goebel, Esposito and Formisano (2006), the initial single voxel threshold was set at $p = .01$, and the minimal cluster size threshold applied to the final statistical maps after Monte-Carlo simulation (1000 iterations) corresponds to a cluster-level false-positive rate (α) of 5%. The separate group maps of the UWD and control groups were tested against zero using a one-sample t-test and thresholded at $p < .01$, with an extended cluster size of 25.

Besides testing for difference in functional segregation we established potential differential

functional integration by performing functional connectivity analyses (C. J. Price, Crinion, & Friston, 2006). We used psychophysiological interaction (Friston et al., 1997) to probe the potential impact of basolateral amygdala damage on the neural network underlying threat perception. Functional coupling between the seed region identified in the between-group analyses and other regions was estimated as a function of the psychological context. The demeaned extracted time course from the seed region (the physiological state) was used to create psychophysiological interaction predictors by multiplying it with the contrast of interest (psychological state). Besides psychophysiological interaction and contrast predictors, the time course of the seed region, motion, and possible outlier predictors were included in the model. After fixed-effect single-subject analysis, a whole-brain random effects group analysis was used to map the difference in connectivity pattern between the UWD and control group. Thresholds were similar as in the functional activation analyses. All statistical maps are shown on the averaged group-aligned surface reconstruction. Talairach coordinates and *t*- and *p*-values of peak vertices are reported.

Results

Functional activation

To complement previous behavioral and EEG studies on face-body compound perception (de Gelder et al., 2014; Kret & de Gelder, 2013; Meeren et al., 2005) and to establish the functional activation in the presence of a functional BLA, we start with reporting the functional maps in the control group only (**Supplementary Table 2-4**). First, results revealed no regions that were activated more for fearful compared to happy bodies regardless of the facial information. Second, the right temporal pole (TP), superior and interior temporal gyrus were activated for happy versus fearful bodies regardless of the facial information. Third, significant clusters were observed for congruent versus incongruent face-body compounds, but not for the inverse contrast. Activity increased for congruent compared to incongruent compounds in the superior frontal gyrus, and ventromedial prefrontal cortex (vMPFC). Fourth, the cingulate gyrus and cuneus were activated for unattended fear bodies compared to unattended happy bodies.

Next we investigated between-group differences in brain regions that showed differential activation for fearful versus happy bodies. UWDs compared to controls showed less activation in the left fusiform gyrus, but more activation in the right anterior inferior parietal lobule (IPL) for fearful versus happy bodies. Directly comparing incongruent with congruent face-body compounds revealed that UWDs compared to controls showed more activation in the medial orbitofrontal cortex (mOFC), ventromedial prefrontal cortex (vMPFC), and the dorsal medial prefrontal cortex (dMPFC). However, UWDs compared to controls showed less activation in the left and right TP. No significant between-group differences were found when

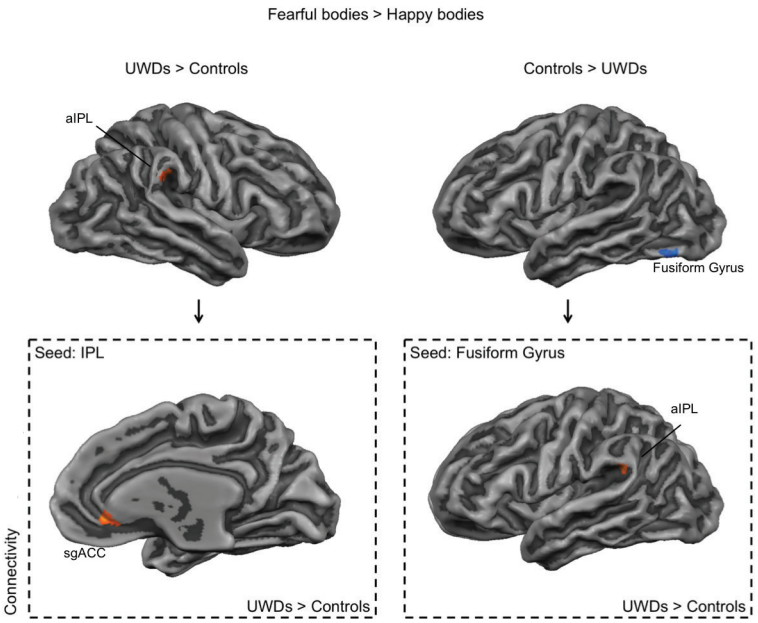


Figure 3. The importance of the IPL in processing of fearful body expressions. The UWD group showed more activation for fearful versus happy bodies in the right anterior IPL, but less activation in the left fusiform gyrus (top). Increased functional connectivity between the IPL and the subgenual ACC, and the fusiform gyrus and the anterior IPL was observed in UWDs compared to controls (bottom).

directly contrasting unattended fear bodies versus unattended happy bodies. The results are presented in **Figure 3-5** and **Table 1**.

We ran an alternative analysis that focused solely on subcortical activation after BLA damage. To allow a fine-grained analysis we ran the same contrasts as in the main analyses but masked the subcortical areas. No significant clusters emerged even with spatial smoothing (4mm Gaussian kernel).

Functional connectivity

In a first analysis, we identified regions that showed functional connectivity with the IPL and the fusiform gyrus during the processing of fearful versus happy body regardless of the facial information. This revealed increased functional connectivity between the IPL and the subgenual anterior cingulate cortex (ACC) in the UWDs compared to controls. Increased coupling between the fusiform gyrus and the anterior IPL was observed in UWDs compared to controls, highlighting the importance of the latter region in threat processing.

Next, we established regions that showed functional connectivity with the mOFC, vMPFC, dMPFC and left and right TP, during the processing of incongruent versus congruent face-body compounds. Interestingly, UWDs compared to controls showed decreased coupling

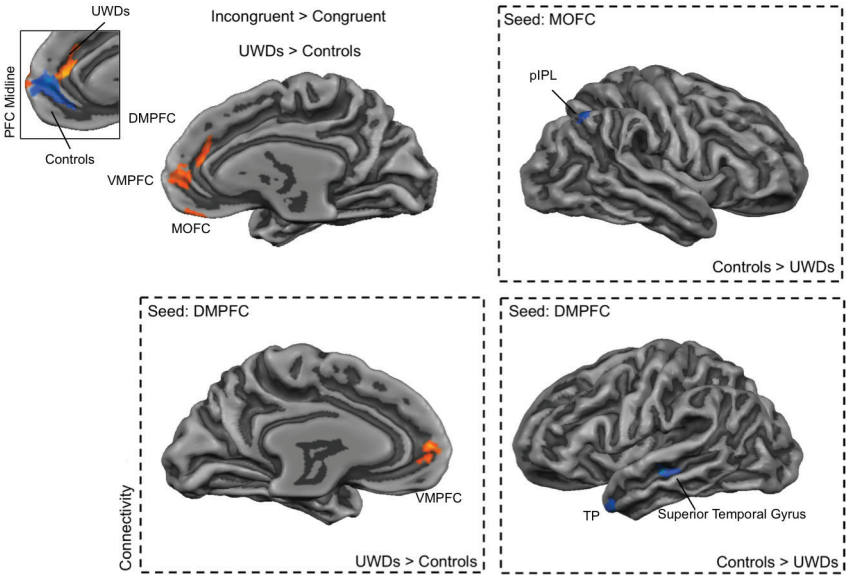


Figure 4. Enhancement of PFC midline activation during ambiguous threat processing after BLA damage. The mOFC, vMPFC, and dMPFC showed increased activity in the UWD group (top left) during ambiguous threat processing. Inset shows increased dMPFC activation for incongruent versus congruent face-body compounds in UWDs, and decreased vMPFC activation for the same contrast in controls. UWDs showed decreased functional connectivity between the mOFC and the posterior IPL, and increased functional connectivity between the cuneus and precuneus with the vMPFC. The dMPFC showed increased coupling with the VMPFC, but decreased coupling with the superior temporal gyrus and TP (right and bottom). Maps are cluster-size corrected except for the within-group maps that are shown with a threshold of $p < .05$ (uncorrected) for illustration purposes.

between the mOFC and the posterior IPL. Increased functional connectivity between the cuneus as well as the precuneus with the vMPFC was observed in the UWDs compared to controls. With the dMPFC as seed region, UWDs compared to controls showed increased coupling with the vMPFC, but decreased coupling with the superior temporal gyrus and TP. Lastly, UWDs compared to controls showed increased functional connectivity between the right TP and the inferior temporal gyrus and bilateral middle temporal gyrus, and decreased functional connectivity between the left TP and mOFC and superior frontal gyrus. **Figure 3-5** and **Table 2** report the results from the functional connectivity analyses.

Basolateral amygdala activation and functional connectivity in controls

To investigate the role of the BLA in threat perception, we tested the contrasts in an exploratory ROI analyses in the control group. ROIs were created based on the cytoarchitectonic probability maps from Amunts et al. (2005) in Eickhoff et al. (2005). Results show more activation for happy compared to fearful bodily expression in the left BLA, $t(11) = 2.43$, $p = .03$. A similar but non-significant pattern was found for the right BLA, $t(11) = 2.04$, $p = .07$. Functional connectivity revealed that the left BLA showed increased connectivity during this contrast with the right primary motor cortex and supplemental motor area, $XYZ^{tal} = 6, -8,$

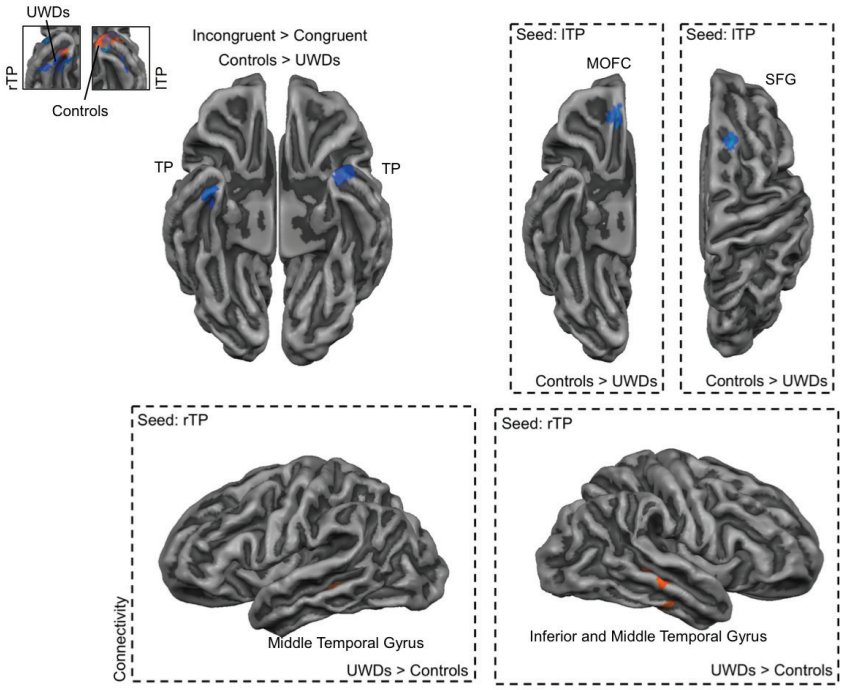


Figure 5. Disruption of TP in ambiguous threat processing after BLA damage. Activity in the TP was reduced for the UWD group during ambiguous threat processing (top left). Inset shows decreased bilateral TP activation for incongruent versus congruent face-body compounds in UWDs, and increased bilateral TP activation for the same contrast in controls. Consistent with the dissociation between the frontal- and temporal-network, increased functional connectivity was observed in the UWDs between the left TP and mOFC and superior frontal gyrus. The right TP showed increased coupling with the inferior temporal gyrus and bilateral middle temporal gyrus (right and bottom). Maps are cluster-size corrected except for the within-group maps that are shown with a threshold of $p < .05$ (uncorrected) for illustration purposes.

54; $t = 7.993$; $p = .000007$, 195 vertices, and the left supplemental motor area, XYZ^{tal} = -5, -3, 52; $t = 4.911$; $p = .000463$; 53 vertices; tested against zero using a one-sample t-test, with a threshold of $p < .01$, extended cluster size of 25 (**Figure 6**). No significant effects were found in the left or right CMA.

Discussion

The aim of the present study was to investigate the consequences of BLA damage on the neural network involved in processing facial and task-irrelevant body expressions of threat. Taken together our results reveal the impact of BLA damage on a PFC-TP-IPL network during the processing of threat. We observed that activation was increased in the IPL but decreased in the fusiform gyrus in UWDs compared to controls for fearful contrasted to happy

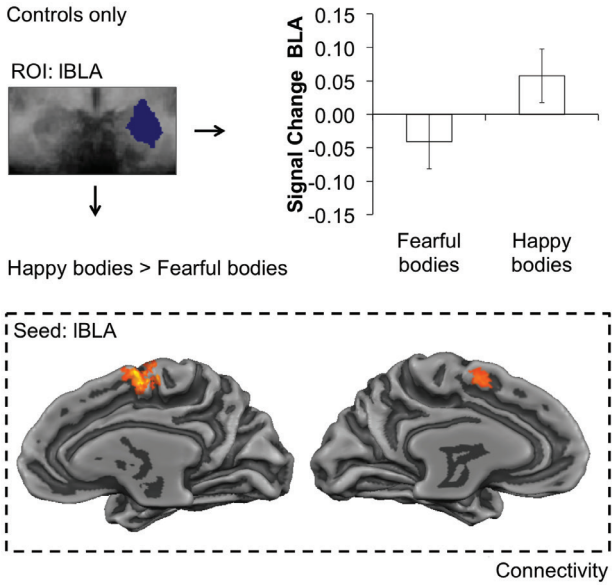


Figure 6. Functional role of the BLA. Activation in left BLA was increased for happy compared to fearful body expressions (top). During this contrast the left BLA showed functional coupling with the left premotor motor cortex and right primary and premotor cortex (bottom).

Table 1 Outcome of main between-group functional activation analyses

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Fearful versus happy body regardless of the facial information								
UWDs > Controls								
Anterior inferior parietal lobule	RH	54	-29	32	40	4.606	.000343	93
Controls > UWDs								
Fusiform gyrus	LH	-41	-69	-12	19	-4.731	.000268	33
Incongruent versus congruent face body compounds								
UWDs > Controls								
Medial orbitofrontal cortex	RH	14	45	-12	11	4.724	.000271	52
Ventromedial prefrontal cortex	RH	9	56	10	10	4.474	.000446	51
Dorsal medial prefrontal cortex	RH	10	38	29	9	4.641	.000320	42
Controls > UWDs								
Temporal pole	RH	40	-4	-31	21	-4.486	.000435	77
Temporal pole	LH	-33	6	-20	38	-4.430	.000487	110

All clusters survive cluster-size correction except the anterior inferior parietal lobule and fusiform gyrus. Area refers to Brodmann area, *N* is number of vertices.

Table 2 Outcome of between-group connectivity analyses

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Fearful versus happy body regardless of the facial information								
Seed: Inferior parietal lobule								
UWDs > Controls								
Subgenual anterior cingulate	RH	8	35	1	24	4.974	.000167	50
Seed: Fusiform gyrus								
Anterior inferior parietal lobule*	LH	-54	-43	25	40	4.926	.000183	51
Incongruent versus congruent face body compounds								
Seed: Medial orbitofrontal cortex								
Control > UWDs								
Posterior inferior parietal lobule	RH	40	-61	42	7	-4.648	.000316	58
Seed: Ventromedial prefrontal cortex								
UWDs > Controls								
Precuneus	RH	7	-69	23	31	5.646	.000047	21
Cuneus	RH	8	-82	26	19	4.650	.000314	22
Seed: Dorsal medial prefrontal cortex								
UWDs > Controls								
Ventromedial prefrontal cortex	LH	-6	52	12	10	5.509	.000060	29
Controls > UWDs								
Superior temporal gyrus	LH	-47	20	3	22	-5.986	.000025	108
Temporal pole	LH	-40	8	-25	38	-4.486	.000435	43
Seed: Right temporal pole								
UWDs > Controls								
Inferior temporal gyrus	RH	55	-22	-17	20	5.564	.000054	55
Middle temporal gyrus	RH	60	-25	-2	21	4.654	.000312	88
Middle temoral gyrus	LH	-54	-36	-1	22	4.076	.000994	37
Seed: Left temporal pole								
Controls > UWDs								
Medial orbitofrontal cortex	RH	11	41	-12	11	-5.356	.000080	36
Superior frontal gyrus	RH	19	26	52	6	-5.475	.000064	38

*Did not survive cluster-size correction. Area refers to Brodmann area, *N* is number of vertices.

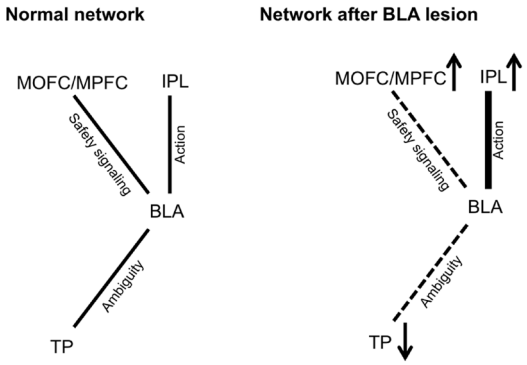


Figure 7. The PFC-TP-IPL network and the processing of threat. Different nodes of the network sustain different roles. While the TP is critical in resolving affective ambiguity, regions in the prefrontal midline signal threat value, safety, and mediate behavioral response selection. The IPL and motor regions play an important role in the selection and execution of the selected behavioral response. Damage to the BLA results in anomalous activity in all three nodes of the network and this could lead to aberrant processing and reactions to threat (right).

bodily expression. Importantly, the IPL showed increased coupling with the subgenual ACC, while the fusiform gyrus showed increased functional connectivity with the IPL in UWDS. Furthermore, BLA damage resulted in differential impact on the frontal-BLA network and temporal-BLA network. In the UWD group regions in the midline (mOFC, vMPFC, dMPFC) showed increased activation to ambiguous threat, but reduced activation in the bilateral TP. Functional connectivity analyses provided further indication for this differential effect and showed reduced coupling between frontal and temporal regions after BLA damage. Reduced coupling between the dMPFC and TP, and superior temporal gyrus during the perception of ambiguous threat was observed in UWD compared to controls. Under similar conditions, we also observed decreased functional connectivity between the left TP and mOFC, and superior frontal gyrus in the UWD participants.

This proposed PFC-TP-IPL network may be involved in several important processes that regulate confrontation with threat along three different axes. In order to respond adaptively, a threatening signal needs to be perceived as a threat, but an ambiguous signal should be interpreted within the different components of the situation. Resolving such affective ambiguity is sustained by the TP. Next, safety signaling and emotion regulation are important to assess threat value and select the appropriate behavioral response; regions in the prefrontal midline have consistently been implicated in these processes. Finally, the selection and execution of action takes place, mediated by the IPL and by motor regions. Damage to the BLA could result in anomalous activity in all three nodes of the network (**Figure 7**) and explain the previously observed hypersensitivity to threat (de Gelder et al., 2014; Terburg, Morgan, Montoya, Hooge, et al., 2012b). We now discuss these steps and the influence of BLA damage in more details.

Temporal pole, resolving ambiguity

Our results are consistent with existing knowledge on afferent and efferent connections and the functional role of the TP, a polymodal association area and part of the extended limbic system (Olson, Plotzker, & Ezzyat, 2007). Connections between TP and the nearby BLA have been reported in monkeys (Aggleton, Burton, & Passingham, 1980; H. T. Ghashghaei & Barbas, 2002), and similar connections were recently demonstrated in humans using in vivo probabilistic tractography (Bach, Behrens, Garrido, Weiskopf, & Dolan, 2011) and meta-analytic connectivity modeling (Bzdok et al., 2013). The TP is also densely connected to midline regions, e.g., orbitofrontal cortex (Kondo, Saleem, & Price, 2003) and the ventral or visual part receives input from extrastriate visual areas, e.g., inferior temporal regions (Markowitsch, Emmans, Irle, Streicher, & Preilowski, 1985). Initial evidence from its role in social emotional processes came from Klüver–Bucy syndrome as well as the temporal variant of frontal temporal dementia (Franzen & Myers, 1973; Thompson, Patterson, & Hodges, 2003). Decreased recognition of facial signals of affect is a dominant factor in both disorders.

As the TP is activated in a variety of social emotional tasks, from face perception to theory of mind, a recent review proposed a unifying role that could underlie the variety of results (Olson et al., 2007). The authors suggested that the TP binds valence to incoming visual signals. It provides the affective meaning to the percept. If so, one would expect that TP also drives the emotional labeling of initial ambiguous social cues. Indeed, increased TP activity was observed when participants view unique stimuli (Asari et al., 2008), or when participants performed an emotion-naming compared to color-naming task (Sinke, Sorger, Goebel, & de Gelder, 2010). Importantly, this proposed perception-emotion linkage is similar to the role of the BLA in emotional coloring of a signal (Benarroch, 2015). Our findings indicate that the TP together with the BLA orchestrates the coupling between emotion and perception. This BLA-TP network establishes the emotional label and biases ongoing neural processes. The decreased activation to incongruent face-body compounds, i.e. ambiguous threat, in the TP and decreased coupling with the mOFC after BLA damage could potentially underlie incorrect labeling of the compound as threat and subsequently biasing upstream neural activity (e.g., midline PFC). This refers to a potential perceptual bias effect in which a task-irrelevant stimulus influences the percept of the task-relevant stimulus in the direction of the former (de Gelder & Bertelson, 2003). This effect is enhanced after BLA damage (de Gelder et al., 2014), and could thus be related to dysfunctional TP functioning and reduced cross-talk between temporal and frontal regions leading to impaired integration of perceptual and emotional processes.

Midline regions, emotion regulation and safety signaling

The regions in the prefrontal midline that showed increased activation in UWDs during ambiguous threat are connected to the BLA (Barbas, 2015) and have consistently been implicated in social emotional processes (Likhtik & Paz, 2015). As highlighted in a study by Barbas and colleagues (2003) the orbital and medial part of the frontal cortex have

different connectivity patterns with regions within the AMG and have distinct but related roles (Grupe & Nitschke, 2013). While the orbitofrontal cortex mediates the emotional and motivation value of the stimulus (Mobbs et al., 2010), the function of the MPFC has been described in terms of situation-response coupling (W. H. Alexander & Brown, 2011). These two processes could be impaired after damage to the BLA. Not only is the threat level of the emotional signal increased, inappropriate action plans are also activated, consistent with the role of the MPFC-BLA network in safety signaling (Likhtik & Paz, 2015). This would hold especially for the ventral part of the MPFC, while the dorsal part has been associated with threat anticipation (Grupe & Nitschke, 2013; Klumpers et al., 2014a). When participants are confronted with a real-life threat but overcame their fear, vMPFC activation increased and was positively related to subjective fear (Nili, Goldberg, Weizman, & Dudai, 2010).

When confronted with threat the emotional signal is hardly unambiguous. Similarly, irrelevant threat can influence the interpretation of a situation. The importance of the AMG, in particular the BLA, and the MPFC in these processes has been noted (Brand, Grabenhorst, Starcke, Vandekerckhove, & Markowitsch, 2007; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Etkin et al., 2004; H. Kim, Somerville, Johnstone, Alexander, & Whalen, 2003; H. Kim et al., 2004; Neta, Kelley, & Whalen, 2013; Nohlen, van Harreveld, Rotteveel, Lelieveld, & Crone, 2014). For example, the BLA codes the subjective interpretation of the emotion of the face (Wang et al., 2014). Interestingly, MPFC and BLA activation are inversely correlated when participants are interpreting ambiguous emotional faces (H. Kim et al., 2003). Similar findings of distraction by irrelevant threat after BLA damage (de Gelder et al., 2014; (Terburg, Morgan, Montoya, Hooge, et al., 2012b), have been obtained in individuals with mood and anxiety disorders (Mathews & MacLeod, 1994). Related to this, changes in connectivity of the MPFC with (parts of) the AMG have been found after early life stress (Malter Cohen et al., 2013), trauma (Thomason et al., 2015) and general anxiety disorder (T. Greenberg, Carlson, Cha, Hajcak, & Mujica-Parodi, 2013; Roy et al., 2013). Deficits in threat discrimination have been related to less differential responses in the vMPFC (T. Greenberg et al., 2013) and to decreased MPFC-AMG connectivity (Cha et al., 2014). In keeping with the potential difference in the ventral and dorsal part of the MPFC, a recent study showed that at rest, coupling between vMPFC (including the subgenual ACC) and AMG was negatively related to state anxiety, while dMPFC-AMG connectivity positively predicted state anxiety (M. J. Kim, Gee, Loucks, Davis, & Whalen, 2011). To conclude so far, the absence of BLA input to the MPFC may lead to dysfunctional threat signaling and regulation.

Inferior parietal lobule and action

Here, we showed increased activation in the IPL for fearful bodily expressions regardless of the facial information in UWDs. Moreover, under the same task conditions increased coupling between the fusiform gyrus and IPL was observed in UWDs. The IPL has been implicated in action observation and representation (Rizzolatti & Matelli, 2003) and maintaining attention (Malhotra, Coulthard, & Husain, 2009). Together with assigning an affective label and

signaling the threat value and potential safety, another crucial step when confronted with threat is the selection and execution of the appropriate action. Several observations in the literature are in line with the possible role of the IPL in representation of action and possible action preparation during threat and the specific influence of the AMG on these processes. The right IPL has been implicated in responding to salient information in the environment (Singh-Curry & Husain, 2009). An early study showing activation of IPL during perception of fearful bodily expressions (de Gelder et al., 2004), was complimented by a later study on the perception of threatening social interaction (Sinke et al., 2010). Directly influencing IPL activity during emotion body perception using online Transcranial Magnetic Stimulation resulted in increased sensitivity for fearful bodily expressions (Engelen, de Graaf, Sack, & de Gelder, 2015). A recent study that investigated face processing in two patients with complete bilateral AMG damage, showed that the one patient that had intact recognition of fearful facial expressions and startle response, also had increased activation in the premotor cortex and IPL to fearful faces (Becker et al., 2012). These findings could be interpreted as increased preparatory responses for action in the face of threat. However, the IPL is a heterogeneous region and encompasses as much as five different clusters (Mars et al., 2011), each with distinctive roles (for example Kwok & Macaluso, 2015). In the present study both the anterior and posterior IPL were implicated in neural circuitry after BLA damage, but under different task conditions and in different hemispheres. The anterior region is connected to premotor cortex and could serve as a crucial hub in the transition from perception to action. In contrast, the posterior part of the IPL is connected to the parahippocampal gyrus and is activated during memory tasks. How these different regions interact with BLA damage and the exact roles they fulfill during threat perception is unknown. Lastly, in control participants the BLA showed more activation to happy compared to fearful bodily expressions and increased functional connectivity between the BLA and the SMA and M1 during this contrast. While the importance of a BLA-motor network for direct BLA-initiated behavioral reactions to threatening situations has been described (Grèzes et al., 2014), the functional meaning of the current findings remains unknown.

Conclusion

Using functional magnetic resonance imaging we studied the neural signature of unattended body expression perception and face-body incongruence in a unique sample with BLA damage. We demonstrated the significance of a PFC-TP-IPL network in the functional integration of and reaction to threatening social stimuli. An imbalance in this network could reflect hypersensitivity for threat as observed after BLA damage.

Supplementary Material

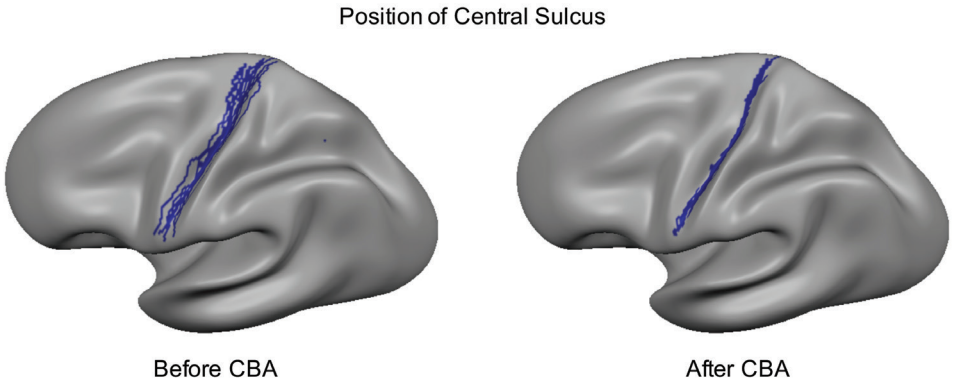
Additional analyses

No between-group differences were found when contrasting emotional faces or bodies versus control stimuli. **Supplementary Tables 5** and **6** and **Supplementary Figure 2** report the significant clusters for the UWD and control group combined. No significant clusters were found between- or within-groups for fearful versus happy facial expression regardless of bodily expression. These functional maps are in line with previous research on face and body perception (de Gelder et al., 2010; Kret et al., 2011; Sabatinelli et al., 2011; van de Riet et al., 2009). Moreover, the lack of significant differences in functional activation between UWDs and controls when perceiving emotional faces and bodies in isolation is in line with behavioral observations of intact emotion recognition of both facial and bodily expressions (de Gelder et al., 2014; Terburg, Morgan, Montoya, Hooge, et al., 2012b).

Supplementary Table 1 Demographic data

	UWDs (*n* = 5)						**Controls (*n* = 12)**
	UWD 1	UWD 2	UWD 3	UWD 4	UWD 6	Mean	Mean
Age	27	34	38	52	39	38±9.14	37.17±5.20
VIQ	97	84	93	82	83	87.80±6.76	86.67±4.68
PIQ	99	87	85	84	87	88.40±6.07	88.17±5.39
FSIQ	98	84	87	81	83	86.60±6.73	85.83±4.43

VIQ: verbal IQ, PIQ: performance IQ, FSIQ: full-scale IQ. Means and standard deviations are reported. No significant differences between groups, p's ≥ .78.



Supplementary Figure 1. Pre- and Post-Cortex-Based Alignment comparison of between-subjects alignment. Position of the left central sulcus for all participants before and after Cortex-Based Alignment shown on a semi-inflated cortex representation.

Supplementary Table 2 Fearful versus happy body regardless of the facial information

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Controls								
Happy > Fear								
Temporal pole	RH	38	-3	-30	21	-3.636	.002225	42
Superior temporal gyrus	RH	49	9	-9	38	-2.919	.010028	39
Inferior temporal gyrus	LH	-50	-16	-25	20	-3.182	.005790	30
UWDs								
No significant clusters								
UWDs and Controls								
No significant clusters								

$p < .01$ (uncorrected) with an extended cluster size of 25. [b] did not survive cluster-size correction. Area refers to Brodmann area, *N* is number of vertices.

Supplementary Table 3 Incongruent versus congruent face body compounds

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Controls								
Congruent > Incongruent								
Superior frontal gyrus	RH	9	26	54	6	-3.996	.001040	30
Ventromedial prefrontal cortex	RH	8	41	-1	10	-2.414	.028110	34
UWDs								
Congruent > Incongruent								
Insula	RH	36	-8	6	13	-3.093	.006981	46
Insula	LH	-34	-4	3	13	-2.608	.019014	51
UWDs and Controls								
Inferior parietal lobule	LH	-32	-46	37	40	-5.817	.000026	68

$p < .01$ (uncorrected) with an extended cluster size of 25. Area refers to Brodmann area, *N* is number of vertices.

Supplementary Table 4 Unattended fear versus unattended happiness

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Controls[a]								
Unattended fear > unattended happy								
Cingulate gyrus	RH	2	-12	27	23	6.603	.000006	47
Cuneus	LH	-3	-71	13	18	2.964	.009131	25
UWDs[a]								
Unattended fear > unattended happiness								
Cingulate gyrus	RH	4	-10	37	24	6.741	.000005	58
Unattended happiness > unattended fear								
Middle frontal gyrus	LH	-41	16	26	46	-3.000	.008479	33
UWDs and Controls[a]								
Unattended fear > unattended happiness								
Cingulate gyrus	RH	4	-10	37	24	6.741	.000005	50
Cingulate gyrus	RH	2	-12	27	23	6.603	.000006	51
UWDs versus Controls								
No significant clusters								

[a] $p < .01$ (uncorrected) with an extended cluster size of 25. Area refers to Brodmann area, *N* is number of vertices.

Supplementary Table 5 Fearful and happy faces > control stimuli for both UWDs and controls

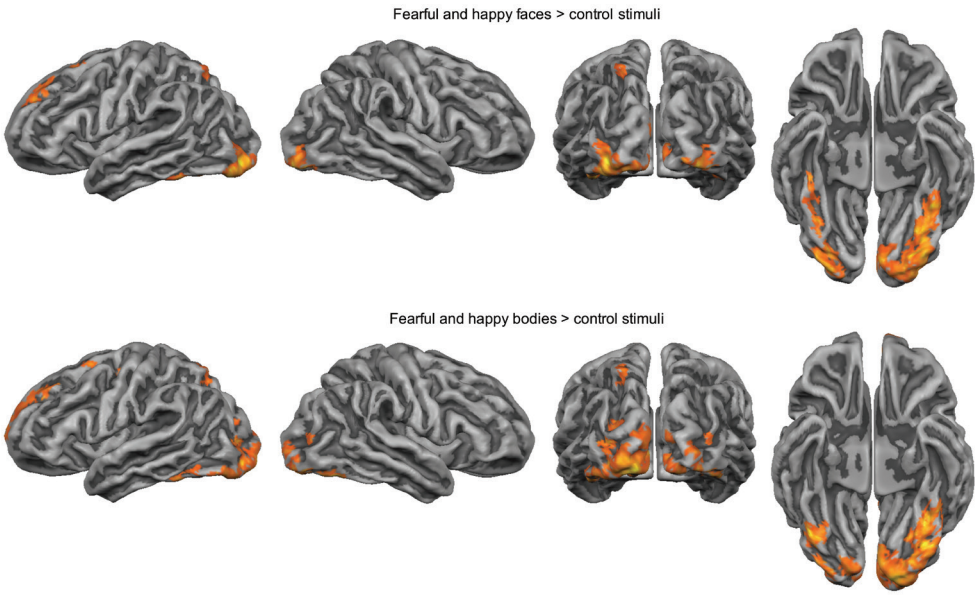
		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Inferior occipital gyrus	RH	27	-87	-9	18	6.756	.000005	183
Fusiform gyrus	RH	35	-55	-13	37	6.321	.00001	133
Lingual gyrus	RH	8	-72	4	18	5.199	.000088	39
Inferior occipital gyrus	LH	-29	-84	-7	18	8.947	< .000001	717
Middle frontal gyrus	LH	-18	18	53	6	4.924	.000153	42
Cuneus	LH	-7	-81	4	17	4.983	.000136	90
Precuneus	LH	-20	-63	49	7	4.411	.000437	76
Superior frontal gyrus	LH	-20	45	31	9	6.493	.000007	109

$p < .01$ (uncorrected) with an extended cluster size of 25. Faces are presented with a grey rectangle, and the control stimulus is a grey oval and rectangle. Area refers to Brodmann area, *N* is number of vertices.

Supplementary Table 6 Fearful and happy bodies > control stimuli for both UWDs and controls

		Talairach coordinates						
	Hemisphere	x	y	z	Area	*t*	*p*	*N*
Lingual gyrus	RH	15	-84	-11	18	5.323	.000069	93
Fusiform gyrus	RH	41	-59	-13	37	7.222	.000002	147
Middle occipital gyrus	RH	28	-89	2	18	4.631	.000277	32
Inferior occipital gyrus	RH	27	-87	-9	18	5.547	.000044	47
Cuneus	RH	8	-90	11	18	4.235	.000631	18
Middle occipital gyrus	RH	36	-76	9	19	4.616	.000286	39
Inferior occipital gyrus	LH	-12	-90	-10	17	8.011	.000001	1189
Precuneus	LH	-20	-58	55	7	4.441	.000411	122
Superior Frontal gyrus	LH	-6	51	29	9	6.979	.000003	151
Precuneus	LH	-24	-71	21	31	4.608	.000291	74
Parahippocampal gyrus	LH	-21	-52	5	30	4.706	.000238	48
Superior frontal gyrus	LH	-20	10	55	6	4.732	.000226	37
Posterior cingulate	LH	-6	-50	19	30	4.238	.000627	56
Precentral gyrus	LH	-29	-9	48	6	4.762	.000212	90
Superior frontal gyrus	LH	-9	62	16	10	4.774	.000207	18

$p < .01$ (uncorrected) with an extended cluster size of 25. Bodies are presented with a grey oval, and the control stimulus is a grey oval and rectangle. Area refers to Brodmann area, *N* is number of vertices.



Supplementary Figure 2. Functional maps during the perception faces and bodies. Faces (top) and bodies (bottom) compared to control stimuli activate regions such as the lingual gyrus, inferior occipital gyrus, fusiform gyrus, inferior occipital gyrus, cuneus, precuneus, and superior frontal gyrus.

Part II

Sympathy - Distress

Motieven zijn niet meer dan geestelijke handvatten om daden te verklaren. Als we zouden stoppen met het opsporen van verklaringen zou er meer worden gehandeld. Het zoeken naar drijfveren levert hooguit drijfzand op. Menigeen laat zich daarin vastzuigen en komt vervolgens niet meer tot actie.

– A.H.J. Dautzenberg - Samaritaan, 2011

Chapter 5

The neural basis of the bystander effect -

The influence of group size on neural activity when witnessing an emergency

This chapter is published as:
Hortensius R & de Gelder B (2014). The neural basis of the bystander effect - The influence of group size on neural activity when witnessing an emergency. *NeuroImage*, 93:53–58.

Abstract

Naturalistic observation and experimental studies in humans and other primates show that observing an individual in need automatically triggers helping behavior. The aim of the present study is to clarify the neurofunctional basis of social influences on individual helping behavior. We investigate whether when participants witness an emergency, while performing an unrelated color-naming task in an fMRI scanner, the number of bystanders present at the emergency influences neural activity in regions related to action preparation. The results show a decrease in activity with the increase in group size in the left pre- and postcentral gyri and left medial frontal gyrus. In contrast, regions related to visual perception and attention show an increase in activity. These results demonstrate the neural mechanisms of social influence on automatic action preparation that is at the core of helping behavior when witnessing an emergency.

Introduction

People are social animals and thrive by interacting with other people. We want company when in misery and we help others when in need, be it physically or by means of donating time or money. Spontaneous helping behavior is observed throughout the animal kingdom and occurs in the absence of explicit reward (Preston, 2013), as observed for example in children and young chimpanzees (Warneken & Tomasello, 2006; Warneken, Hare, Melis, Hanus, & Tomasello, 2007). Yet these familiar intuitions were challenged in the sixties by a well-known finding in social psychology that revealed a dark side of human interaction, the 'bystander effect'.

The bystander effect refers to the decrease in helping behavior of an onlooker when a person is in need and multiple bystanders witness the emergency (Darley & Latané, 1968; for a recent meta-analysis see Fischer et al., 2011). Several explanations of this effect have been suggested among which pluralistic ignorance, diffusion of responsibility, and evaluation apprehension are mentioned most frequently (Fischer et al., 2011). All of these reflect interpretations that appeal to high level cognitive notions and provide a top–down explanation for social behavior. While these interpretations undoubtedly shed some light on group influences on individual behavior, they do not directly point to an underlying single or composite neural mechanism.

In line with a bottom-up explanation of social phenomena and mechanisms rooted in cross-species similarities (de Waal & Ferrari, 2010), the perception–action model proposes that merely observing someone in need will trigger a cascade of somatic and autonomic responses that have motor and emotional behavioral consequences (Preston & de Waal, 2002). Observing and responding to distress of another individual can be seen as a basic evolutionarily conserved mechanism, shared with other animals (de Waal, 2008; Preston, 2013), that point to a less cognition based or more unintentional, implicit, action based process. Thus, witnessing an emergency (e.g., a person fainting) results in preparation of automatic helping behavior, and consequently in activation of brain areas related to preparation for action and coupling between the situation and adaptive behavior. Indeed, recent research using a variety of behavioral and neurophysiological methods has shown that already static social emotional information (e.g., emotional scenes or expressions) influences activation in the primary motor cortex (Hajcak et al., 2007; Schutter et al., 2008b), supplemental motor area, middle frontal gyrus and the cingulate gyrus (de Gelder et al., 2004) and that this can be explained as a preparation for action (Frijda, 1986; Lang, 1994). The next question is whether this automatically triggered preparation for action is already influenced by social context, i.e. group size.

In the present study we investigated the neurofunctional basis of group influences on individual helping behavior. We used videos depicting the scene of an emergency and we manipulated the presence and group size of other persons at the scene. To tap into the automatic, attention-

independent processes underlying helping behavior, participants performed a color detection task that was unrelated to the stimulus conditions and did not require cognitive involvement, or recognition or understanding of the situation. We tested the hypothesis that an increase in group size will decrease activity in regions which lie at the core of automatic preparation for action in the observer. This result would provide evidence of the influence of social context on automatic helping behavior as measured by a reduction in activation in the areas related to action preparation.

Materials and methods

Participants

Seventeen healthy, right-handed volunteers, (three males) aged between 18 and 27 years participated in exchange for money. Participants reported no psychiatric or neurological history, normal or corrected-to-normal vision, and no current use of psychoactive medications, except for women taking oral contraceptives. Written informed consent was obtained and participants were unaware of the aim of the study. The experiment was carried out in accordance with the standards established by the Declaration of Helsinki and approved by the local ethics committee.

Stimuli

A real life situation served as a starting point for creating short movie clips using local amateur actors. In each scenario the central character was a woman shown fainting and falling to the floor but the number of people passing by her differed. Group size consisted of none, one, two or four bystanders (by0, by1, by2, by4; **Figure 1A**). The people passing by were instructed to simply walk by when the woman fainted without intervention, but were allowed to look at the person in need if they wanted to or did so spontaneously. The notion of bystander usually refers to the situation where a crowd watches an emergency situation involving an individual, but experimental studies investigating the bystander effect have used multiple techniques (see Fischer et al., 2011) ranging from physical (increase in group size) to virtual (internet). Here our aim was to use a bystander situation that can occur in real life and allowed testing in the well-controlled environment of a MRI scanner. We therefore used dynamic stimuli from the viewpoint of a person looking across the street. Examples of the stimuli are shown in the **Video**. As an illustration of the realism and the notion of automatic helping behavior, we report the following anecdote. During the recording of one scene a woman who was not part of the group of actors rushed onto the set in distress and offered help to the woman 'fainting'.

In total six unique videos per scenario were shot. The raw footage was edited using Adobe After Effects CS5 (Adobe Systems Inc., San Jose, CA, USA) and grayscale movies (720 × 576 pixels, 25 frames/s, total duration of 3 s) were created. Movies were slightly blurred to reduce

Video. Scan the QR code to see examples of the stimuli.

availability of facial information. Furthermore, a selection of the movies with none, one, two, or four people passing by was inverted and reversed (Control). In addition, another control scenario was created in which the person fainting, without bystanders present, stood up again (Standing). In this scenario, half of the movies consisted of the actress standing up again, whereas the other half was due to lack of material reversed and slowed down footage of the last part of the falling sequence to create the illusion that the person was standing up again. Movies were mirrored and three colored dots (80ms for each dot) were added to each movie for task purposes (see below). The dots always appeared on the bodies of people in the scene.

Design and procedure

Subjects performed a color-naming task as used previously (see Pichon et al., 2012; Sinke et al., 2010). This task is unrelated to the effect of interest. Participants were instructed to indicate if the three colored dots presented during the movie were of the same or different colors (**Figure 1B**). To control for possible motor anticipation the response alternatives appeared randomly left or right of the fixation cross and participants were instructed to react after offset of the stimulus. Participants performed four practice trials on different stimuli, showing the actress standing and waiting, outside of the scanner. There are several advantages of using this task. It counteracts possible social desirable thoughts and ruminations. The participants remain naive to the goal of the experiment since they are instructed to perform a color-naming task and the content of the movie is never mentioned to them. Thus, it will prevent excessive contemplation, but still allow a full comprehension of the social situation. This is of importance, since we wanted to tap into the whole range of activation related to responding to an emergency and not only into higher order, cognitive processes. This task counteracts possible differences in attention and the use of cognitive resources during the course of the experiment, between subjects and conditions. It will also allow a more ecological approach, as the demands on the subjects are similar as outside the laboratory. Instead of active looking for possible emergency situations, humans are most of the time suddenly confronted with an emergency while they are engaged in something else.

A slow-event related design was used. Following presentation of the stimuli (3 s), an answer screen (2 s) and a fixation interval (9 or 11 s) were presented. Each session consisted of 4 experimental functional runs. Each run consisted of 36 trials and a total of 144 trials were

presented with 24 trials per condition (2 repetitions of each unique and mirrored video). For 9 participants an anatomical scan was performed after 2 runs, while the anatomical scan of the other seven subjects was obtained in a separate session in which they performed a different experiment (Huis In 't Veld & de Gelder, 2015).

Stimuli were presented using Presentation Version 14.8 (www.neurobs.com), projected onto a screen located at the end of the scanner bore. Participants viewed the stimuli via a mirror mounted with an angle of ±45° to the head coil. Each movie started at a new scan volume, as the onset of the stimuli was synchronized to a trigger from the scanner.

Image acquisition

Data was acquired with a 3-Tesla head scanner (MAGNETOM Allegra, Siemens, Erlangen, Germany). Earplugs were used to attenuate scanner noise and padding was used to reduce head movements. Gradient-echo $T2_*$-weighted transverse echo-planar images (EPI) with blood oxygenation level-dependent (BOLD) contrast were used for functional scans. Each volume contained 32 axial slices acquired in an ascending-interleaved manner (repetition time (TR) = 2000 ms, echo time (TE) = 30 ms, slice thickness = 3.5 mm, no gap, flip angle (FA) = 90°, field of view (FOV) = 224 x 224 mm2, matrix size = 64 × 64). We collected a total of 267 functional volumes for each subject as well as high-resolution T1-weighted anatomical images using parameters from the Alzheimer's Disease Neuroimaging Initiative (TR = 2250 ms, TE = 2.6 ms, slice thickness = 1 mm, no gap, FA = 90°, FOV = 256 x 256 mm2, matrix size = 256 × 256).

fMRI preprocessing and analysis

Image preprocessing was carried out using BrainVoyager QX version 2.6 (Brain Innovation, the Netherlands, www.brainvoyager.com). The first 2 volumes of each run were discarded to avoid T1 saturation effects. Preprocessing of functional data consisted of incremental linear trend removal, temporal high-pass filtering, a rigid-body algorithm to correct for small movements between scans and spatial smoothing with a 4 mm Gaussian kernel. Functional and anatomical data were normalized into Talairach space.

To map the increase and decrease in percentage change of the BOLD signal with the increase in group size a parametric-coded single-subject fixed-effects general linear model (GLM) with control, standing and response screen as additional predictors was used (**Figure 1C**). Next, at the group level a random-effects GLM was performed. In addition, we calculated the following contrasts using a dummy-coded GLM. The influence of visual complexity was determined with a control > (by1 + by2 + By4) contrast and the effect of witnessing an emergency was investigated with the by0 > standing contrast. All analyses were restricted using a mask to exclude non-brain voxels.

The statistical threshold for single voxels was set at FDR < .05 with a cluster threshold of

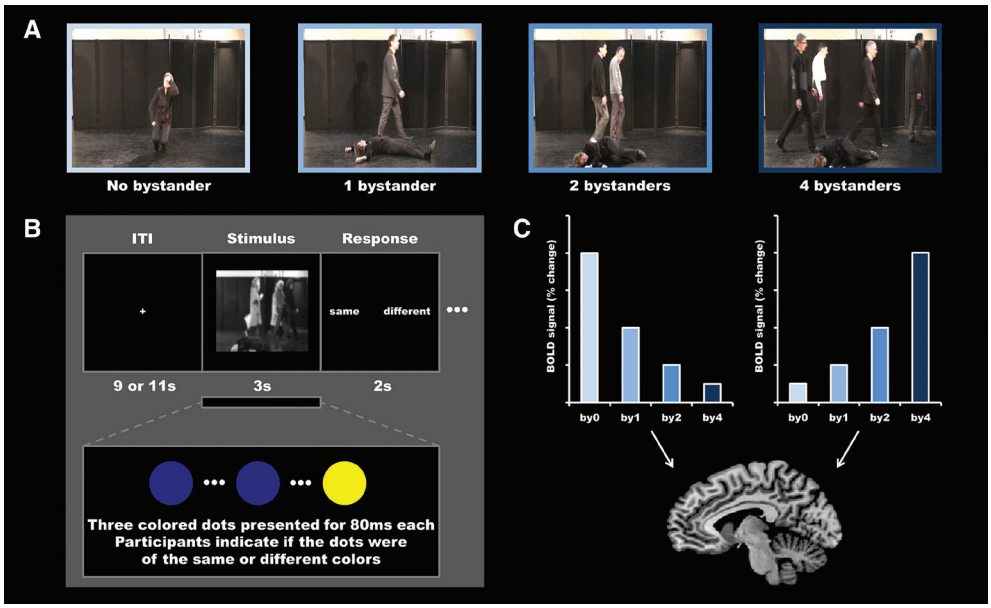


Figure 1. Stimuli, task and illustration of the analysis. Unprocessed stills of examples of the used scenarios where group size consisted of none, one, two or four bystanders (A). Overview of the color-naming task (B). A parametric analysis was used to map the increase and decrease in percentage change of the BOLD signal with the increase in group size (C).

40. For several maps we calculated the corrected cluster-level threshold (Forman et al., 1995; Goebel et al., 2006). This method corrects for multiple cluster tests across space. First, a single voxel threshold of p = .005 (uncorrected) was used for initial statistical maps. As it was our analysis of interest, we used a single voxel threshold of p = .05 (uncorrected) to calculate the corrected cluster-level threshold for the parametric decrease in BOLD signal with the increase in group size. Next, a whole-brain correction criterion was calculated estimating a false-positive rate for each cluster taking into account the spatial smoothness of the map. This was established by means of Monte-Carlo simulation (5000 iterations) and the minimum cluster size threshold applied to the statistical maps corresponds to a cluster-level false-positive rate (α) of 5%. Cluster size is reported in number of anatomical voxels and the used statistical threshold is indicated for each analysis in the corresponding table. Statistical maps are displayed on the Colin 27 average brain.

Results

Data from one participant was discarded due to technical failure. Mean accuracy±SD during the color-naming task was 96.53±2.14. Comparing the different conditions revealed no differences in performance (p's ≥ .09), indicating that task difficulty was not a factor in the fMRI analyses.

Decrease in brain activity with the increase in group size

The parametric analysis showed a decrease in activity with the increase in group size in the left medial frontal gyrus and the left postcentral gyrus extending to the precentral gyrus (**Figure 2A** and **Table 1**).

Increase in brain activity with the increase in group size

The right superior occipital gyrus, right lingual gyrus, left cuneus, and left middle temporal gyrus showed a parametric increase in activity (**Figure 2B** and **Table 1**). The control > bystander contrast revealed significant clusters in the fusiform gyrus, precuneus, cuneus and middle temporal gyrus of the right hemisphere (**Table 2**). Importantly, these regions only overlap with regions showing an increase, but not a decrease, in activation with the increase in group size.

Brain activity related to witnessing an emergency

The right cuneus was more active when the person was shown fainting and falling down without bystanders compared to the same person standing up again without bystanders. In

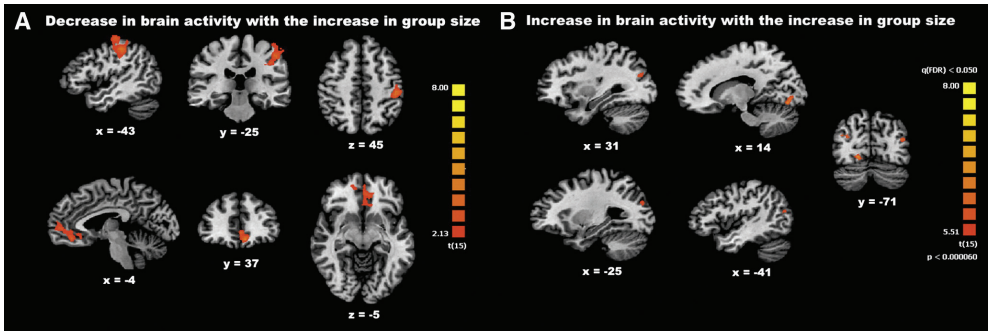


Figure 2. Results from parametric analysis. Regions showing a decrease (A) or increase (B) in activation with the increase in group size.

Table 1. Parametric effect of number of bystanders

		Talairach coordinates					
	Hemisphere	x	y	z	*t*	*p*	Cluster size
Decrease in activity with the increase in group size[a]							
Medial Frontal Gyrus	LH	7	37	-9	4.94	.000177	2998
Postcentral Gyrus[b]	LH	-43	-26	45	4.19	.000783	3511
Increase in activity with the increase in group size[c]							
Lingual Gyrus	RH	14	-74	-6	9.93	.000000	719
Superior Occipital Gyrus	RH	32	-74	24	7.22	.000003	246
Cuneus	LH	-25	-80	24	6.60	.000008	58
Middle Temporal Gyrus	LH	-46	-68	18	7.65	.000001	166

[a] p <.05, cluster size corrected; [b] extending to the precentral gyrus; [c] FDR <.05.

addition, the right fusiform gyrus, right inferior temporal gyrus and left middle temporal gyrus and right middle occipital gyrus were more active when the person was standing up instead of falling down (**Table 3**).

Discussion

The present study investigated the influence of group size on neural activity during unintentional observation of an emergency. The left precentral and postcentral gyri and the left medial frontal gyrus showed a decrease in activity with the increase in group size. In contrast, regions involved in visual processing and attention showed an increase in activity with the increase in group size. We propose that these results support the conclusion that group size during an emergency already influences activity in brain regions sustaining preparation for action.

Action is at the core of survival of the individual and the group (Panksepp, 1998), and activity in motor regions, including the precentral gyrus, has been found to be mediated by social emotion information (de Gelder et al., 2004; Hajcak et al., 2007; Pichon et al.,

Table 2. Control > Bystander

		Talairach coordinates					
	Hemisphere	x	y	z	*t*	*p*	Cluster size
Fusiform Gyrus	RH	29	-47	-3	4.97	.000169	583
Fusiform Gyrus	RH	23	-65	-9	6.47	.000011	709
Precuneus	RH	32	-65	30	5.34	.000083	612
Cuneus	RH	2	-83	18	4.62	.000330	1194
Middle Temporal Gyrus	RH	38	-53	3	4.94	.000179	401

$p < .005$, cluster size corrected.

Table 3. Falling versus Standing

		Talairach coordinates					
	Hemisphere	x	y	z	*t*	*p*	Cluster size
Falling > Standing							
Cuneus	RH	-1	-95	18	6.14	.000019	804
Standing > Falling							
Fusiform Gyrus	RH	38	-35	-12	7.06	.000004	2020
Inferior Temporal Gyrus	RH	44	-68	0	6.45	.000011	2863
Middle Occipital Gyrus	RH	29	-83	3	4.67	.000300	373
Middle Temporal Gyrus	LH	-46	-65	9	6.16	.000018	4573

$p < .005$, cluster size corrected.

2012; Schutter et al., 2008b). The observed decrease in this area is in line with the proposed reduction in automatic action preparation with the increase in group size. This provides a new perspective on the negative influence of group size on helping behavior as observed in the bystander effect. Automatic mechanisms can underlie the processing, action tendencies and the behavioral consequences of social cues and these are already influenced by contextual information (Gawronski & Cesario, 2013). The selection of an action, i.e. the decision to help or not, and providing help itself, can be implicit in nature, unintentional, independent of cognitive deliberation, while still be context-dependent (Preston, 2013). Indeed, empathic responses seem to be stimulus-driven and independent of task instruction (Avenanti, Minio-Paluello, Bufalari, & Aglioti, 2006). Moreover, previous studies using the same color-detection task as used here support the conjecture of automatic action preparation in response to social emotional information regardless of attention (Pichon et al., 2012; Sinke et al., 2010). For example, observing someone threatening another individual triggered activation in the premotor area and putamen regardless of the focus of attention (Sinke et al., 2010).

In addition to the precentral gyrus, the postcentral gyrus corresponding to the somatosensory cortex, and the medial frontal gyrus showed a decrease in activation with the increase in group size. Besides its importance for proprioception, the somatosensory cortex was found to be activated during the encoding of actions for later enactment (Eschen et al., 2007). The somatosensory cortex, but also the medial frontal cortex, is activated during representations and regulation of emotional states of oneself and other people (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Etkin, Egner, & Kalisch, 2011; Pitcher, Garrido, Walsh, & Duchaine, 2008). The medial frontal cortex has been characterized as the visceral motor cortex (Neafsey et al., 1993) and is connected to a large number of brain areas relevant for adaptive behavior such as the amygdala, hypothalamus and periaqueductal gray (Gabbott et al., 2005). Moreover, it is involved in sustaining the associations between events and corresponding adaptive responses (W. H. Alexander & Brown, 2011; Euston et al., 2012). Thus, the parametric decrease in this area may reflect implicit decoupling between the observation of the emergency and action preparation in view of the appropriate behavioral response (i.e. helping). Indeed, activity in the medial frontal cortex has been linked to daily helping behavior of both friends and strangers (Rameson, Morelli, & Lieberman, 2012).

While the present results suggest that group size has already an effect at the level of preparation for action, this does not mean that other processes could not also play a role. For example, it was recently shown that in-group membership increases confrontational intervention in a bystander situation (Slater et al., 2013). Alternatively, higher-order processes could interact with automatic processes by possibly down-regulating corresponding neural activity. Therefore, in the present research we wanted to tap into automatic processing by focusing the attention of the participant on an unrelated task, in order to keep cognitive resources and attention at a constant level between conditions and throughout the course of the experiment. This was successful as no effect of the increase in group size was found on

performance during the color-naming task. It is therefore unlikely that cognitive processes could explain the present results. However, future research should manipulate task demands (e.g., difficulty, attention, instruction) to disentangle higher-order from automatic processes when witnessing an emergency.

One may argue that the activation in motor areas we find here relates to the motor response during the color-naming task. But this is unlikely in view of the fact that several measures were taken to rule out the possibility that this could explain or mediate part of the results. First, a delayed response was used (i.e. participants responded after offset of the stimulus) thereby increasing the possibility to disentangle task-related and stimulus-related activations. Second, the response alternatives appeared randomly on the left or right of the screen in order to prevent motor anticipatory activity. Third, the response screen was also taken into account in the regression model in order to control for motor-related confounds. It is therefore unlikely that the present results are task- and not stimulus-driven.

The increase in activation with the increase in group size was limited to visual regions. It is suggested that vision is always affective vision (Pessoa, 2012). For instance, emotionally arousing content increases activation in extrastriate areas (Lang et al., 1998). However, given the overlap between areas showing an increase in activity with the increase in group size and areas activated in the visual control contrast, it is likely that the former activation is due to the increase in visual complexity.

A recent meta-analysis suggests that the bilateral insular cortex and medial and anterior cingulate cortex are activated when witnessing another individual's suffering (Lamm, Decety, & Singer, 2011). In the present study, we found that when witnessing an emergency without bystanders, activation was limited to the right cuneus. We provide two explanations for this contrast with the existing literature. First, empathy consists of multiple different phenomena ranging from emotion contagion to sympathy to cognitive empathy (F. Deutsch & Madle, 1975; Preston & de Waal, 2002). The present study did not focus on deliberate observation of an individual's suffering but on the consequence of unintentional observation of an emergency. Using a color-naming task we might have canceled cognitive empathy and other higher-order forms of empathy and more tapped into reflexive preparation to help (Preston & de Waal, 2002). Thus, one would expect that if the participant is given more time to contemplate the event, activation would shift to brain regions important for higher order empathic processes. Another explanation might be the occurrence of a repetition effect. The initial perception to the emergency might result in a strong emotional reaction in the subject, but repetitive presentation might reduce this reaction and corresponding activation patterns. While in the present study this possible effect might be reduced given the implicit processing of the stimuli, it might still have affected emotional and empathic reactions and thus corresponding neural patterns.

In conclusion, our results provide insight in the neural mechanisms of the bystander effect and show that group size influences neural responses already at the level of preparation for action. Subsequently, this reduces the individual's spontaneous tendency to help. The present study illustrates how complex and well-described social phenomena such as the bystander effect can be investigated inside the laboratory and how this may lead to a better understanding of the underlying neural mechanisms of social behavior.

Chapter 6

Personal distress and the influence of bystanders on responding to an emergency

This chapter is in revision as:
Hortensius R, Schutter DJLG & de Gelder B. Personal distress and the influence of bystanders on responding to an emergency.

Abstract

Spontaneous helping behavior during an emergency is influenced by the personality of the onlooker and by social situational factors such as the presence of bystanders. Here, we sought to determine the influence of sympathy, an other-oriented response, and personal distress, a self-oriented response, on the effect of bystanders during an emergency. In four experiments, we investigated whether trait levels of sympathy and personal distress predicted responses to an emergency in the presence of bystanders using behavioral measures and single-pulse Transcranial Magnetic Stimulation. Sympathy and personal distress were expected to be associated with a faster response to an emergency without bystanders present, while only personal distress would predict a slower response to an emergency with bystanders present. Results of a cued-reaction time task showed that people who reported higher levels of personal distress and sympathy responded faster to an emergency without bystanders (Exp. 1). In contrast to predictions, perspective taking but not personal distress was associated with slower reaction times with an increasing number of bystanders during an emergency (Exp. 2). However, the decrease in motor corticospinal excitability, a direct physiological measure of action preparation, with the increase in the number of bystanders was solely predicted by personal distress (Exp. 3). Incorporating cognitive load manipulations during the observation of an emergency suggests that personal distress is linked to an effect of bystanders on reflexive responding to an emergency (Exp. 4). Taken together, these results indicate that the presence of bystanders during an emergency reduces action preparation in people with a disposition to experience personal distress.

Introduction

When confronted with a person in distress, most people react to the situation by rushing forward to help. Generally, two types of emotional reactions to an emergency situation that promote helping behavior are distinguished, namely personal distress and sympathy (for a review see C. D. Batson et al., 1987). Both state and trait levels of sympathy and personal distress have been linked to helping behavior (Archer, Diaz-Loving, Gollwitzer, Davis, & Foushee, 1981; Carlo, Allen, & Buhman, 1999; Cialdini et al., 1987; Coke, Batson, & McDavis, 1978; Eisenberg & Miller, 1987; Eisenberg, Fabes, et al., 1989a; Eisenberg, Miller, et al., 1989b). However, sympathy and personal distress markedly differ in terms of underlying motivations. The former results in altruistic-driven (other-oriented; feelings of sympathy and compassion for the victim) and the latter in egoistic-driven (self-oriented; feelings of distress and discomfort in the observer) helping behavior (C. D. Batson et al., 1987; C. D. Batson, O'Quin, Fultz, Vanderplas, & Isen, 1983; M. H. Davis, 1983).

Although feelings of personal distress and sympathy each lead to helping behavior, the underlying incentive to help may thus be very different. As such it could be argued that social situation or context could have a different influence on these two factors. Indeed, studies have shown that helping behavior, driven by personal distress, is reduced when the aversive situation can be easily avoided, while sympathy-driven helping behavior is not (C. D. Batson et al., 1983; C. D. Batson, Duncan, Ackerman, Buckley, & Birch, 1981; Coke et al., 1978; Toi & Batson, 1982). Contextual effects have also been reported for trait measures of other- and self-oriented responses to emergency situations (C. D. Batson, Bolen, Cross, & Neuringer-Benefiel, 1986; Carlo, Eisenberg, Troyer, Switzer, & Speer, 1991; Romer, Gruder, & Lizzadro, 1986). Romer and colleagues (1986) reported that people with an altruistic orientation offered the most help when no compensation (experimental credits) was given. Interestingly, helping was reduced in this group when compensation was offered. Furthermore, social evaluation of the latent helper by the experimenter influences the relation between personal distress and helping behavior, but not between sympathy and helping behavior (Archer et al., 1981; Eisenberg, Miller, et al., 1989b; Fultz, Batson, Fortenbach, McCarthy, & Varney, 1986). For example, directly manipulated and self-reported concerns for social evaluation did not account for the positive relation between trait sympathy and helping behavior (Eisenberg, Miller, et al., 1989b). Taken together, social context has a more pronounced and negative influence on the relation between personal distress and helping behavior than helping behavior driven by sympathy.

Helping behavior also decreases when more people are present at the scene. This phenomenon is known as the "bystander effect" (Darley & Latané, 1968). Several cognition-based explanations, including notions like diffusion of responsibility or pluralistic ignorance have been given for this lack of helping behavior (Latané & Darley, 1970). The decision model proposed by Latané and Darley (1970) describes the explicit cognitive calculation in

terms of attentional capture, evaluation, responsibility, beliefs and the conscious decision to help. Interference can occur at any of these levels. However, this model does not cover the entire range of explanations (for example S. M. Garcia, Weaver, Moskowitz, & Darley, 2002), or the emerging view on helping behavior and prosocial behavior (Preston, 2013; Preston & de Waal, 2002; Rand & Nowak, 2013; Zaki, 2014). Helping behavior is observed across species, ranging from rats (Ben-Ami Bartal, Decety, & Mason, 2011; Ben-Ami Bartal, Rodgers, Bernardez Sarria, Decety, & Mason, 2014; Márquez, Rennie, Costa, & Moita, 2015; Sato, Tan, Tate, & Okada, 2015) to chimpanzees (Warneken et al., 2007; Warneken & Tomasello, 2006). The act of helping is not necessarily a deliberate one. As was described in Preston (2013), providing help is rooted in an evolutionarily conserved mechanism, offspring care, with fixed action patterns (see also Decety, Norman, Berntson, & Cacioppo, 2012). This bottom-up view highlights the importance of a neural mechanism for fast context-dependent, goal-directed responses. Merely the observation of a salient emotional situation – for example, witnessing a person in distress – triggers a wide variety of reflexive responses (de Waal, 2008; Preston & de Waal, 2002), including increased action readiness and preparation (e.g., fight-flight responses) (de Gelder et al., 2004; Frijda, 1986; Grèzes & Dezecache, 2014; Hajcak et al., 2007; Lang et al., 1993; Schutter et al., 2008b).

In a recent functional magnetic resonance imaging (fMRI) study, we investigated the neural basis of the bystander effect by manipulating the number of bystanders present at an emergency (Hortensius & de Gelder, 2014). The results showed a decrease in activity with an increase in the number of bystanders in the left precentral and postcentral gyrus and medial frontal gyrus when participants witnessed an emergency. This suggests that the number of bystanders influences neural responses in brain regions dedicated to motor-related behavior, possibly indicative of action preparation during the observation of emergency (de Gelder et al., 2004; Hajcak et al., 2007; Pichon et al., 2012; Schutter et al., 2008b). An outstanding question is how trait levels of sympathy and personal distress influence the effect of bystanders on action preparation.

In the present study, we examined the extent to which trait sympathy and personal distress predict reaction times during a cued-reaction time task when participants witnessed an emergency without bystanders (Exp. 1), and when the number of bystanders was manipulated during an emergency (Exp. 2). We hypothesized that both trait personal distress and sympathy would predict faster responses to an emergency, as compared with a nonemergency situation without bystanders (Exp. 1). Furthermore, we expected that an increase in the number of bystanders would result in slower responses to an emergency situation. Based on the previously found negative influence of social context (e.g., possibility to escape the situation, exposure to social evaluation) on helping behavior driven by personal distress, we anticipate that this slowing of reaction times with an increase in the number of bystanders will be predicted by personal distress and not sympathy (Exp. 2).

Experiment 1 and 2

Methods

Participants

Sixty-two volunteers, between 18 and 29 years of age, participated in exchange for course credits. In all, 18 female and 12 male students took part in Experiment 1, and 21 different female and 11 different male students took part in Experiment 2. Right-handed (n = 56), left-handed (n = 5) and ambidextrous (n = 1) participants were included. In Experiment 2, the data from two participants were lost due to technical failure and were replaced by new volunteers. Participants were unaware of the aim of the study. Written informed consent was obtained, and the experiment was carried out in accordance with the standards set by the Declaration of Helsinki.

Stimuli

The stimuli used in Hortensius & de Gelder (2014) were slightly modified for the present purpose. A simulation of a street-side event was used as a starting point to create an emergency situation in which a woman was shown fainting and falling to the floor. During this emergency, people were passing by (henceforth: the bystanders). The original short video clips were recorded from the viewpoint of a person looking across the street. The grayscale video clips were blurred in order to reduce visibility of facial expressions and other non-relevant information. In the present experiment, we made several changes to the existing video clips. First and foremost, besides the fainting and falling scenario, we created a nonemergency situation in which the woman stood up in a completely natural way. Using Photoshop CS2 (Adobe Systems Inc., San Jose, CA, USA) we overlaid the bystander sequence on both types of situations. This made sure that (a) the emergency and nonemergency situations were similar in terms of bystanders, but differed only in the action of the woman, and (b) the action of the woman was similar for all the bystander conditions. Both the increase in visual complexity between the emergency and nonemergency situations and the emotional impact of the action of the woman with different numbers of bystanders were kept similar. To increase realism, actions of the target character and bystanders happened within the same time window. In total, six scenarios were created, with the situation being either an emergency (woman falling) or a nonemergency (woman standing up) and the number of bystanders consisting of none, one or four bystanders**.** Six unique videos per scenario (three different actors and groups, with two repetitions) lasting 1s were created. **Figure 1** and the **Video** show examples of the stimuli used.

In addition, scrambled versions of videos were made in MATLAB (version R2011b, The MathWorks Inc., Natick, MA, USA) using a Fourier-based transformation of each phase spectra of every video frame. This procedure removes all social-emotional information except for low-level visual parameters such as movement and spatial frequency. These scrambled

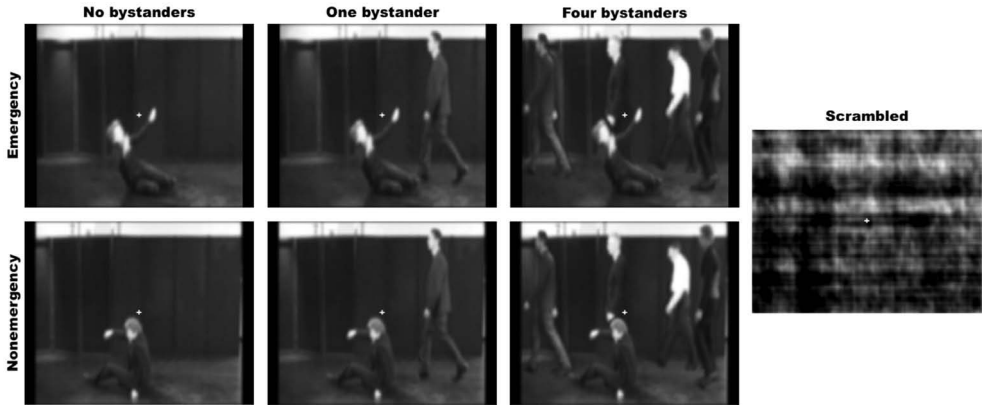


Figure 1. Stills of the stimuli used in the study.

videos served as a low-level visual control condition.

Task

To measure the effect of an emergency on reaction times, an adapted cued-reaction time task was used. In a cued-reaction time task, a preparation cue is presented before a response cue, which allows the participants to prepare their response (Hagura, Kanai, Orgs, & Haggard, 2012; van Boxtel & Böcker, 2012). A video clip was presented in between the onsets of the preparation cue and the go cue (**Figure 2**). Following a preparation cue (blue dot) at the onset of the video clip, a go cue (green dot) was presented after 1s – that is, the offset of the video clip – to inform the participant to respond. Both cues were presented for 160ms. On 20% of the trials in Experiment 1, and 12.5% of the trials in Experiment 2, a no-go cue (red dot) was presented.

The social situation may influence ongoing emotional and cognitive processes that can be measured by means of reaction times after offset of the video. This rationale is taken from other studies using emotional Stroop tasks, gaze cueing paradigms, and emotional go/no go tasks to map individual differences in processing emotional and social information (Mathews & MacLeod, 1994; Nosek, Hawkins, & Frazier, 2011). The present setup allows us to assess responses to an emergency without explicit measures in a relatively well-controlled environment and reaction times are taken as an index of action preparation during the non-intentional observation of an emergency.

Questionnaire

Empathy can be thought of as a multifaceted concept consisting of phenomena like mimicry, sympathy and perspective taking (Preston & de Waal, 2002). In line with this multidimensional approach, we used the Interpersonal Reactivity Index (IRI) to measure trait empathy (M. H. Davis, 1980; 1983; De Corte et al., 2007). This questionnaire assesses several different aspects

Video. Scan the QR code to see examples of the stimuli.

of empathy. Besides perspective taking and fantasy (i.e., the ability to transpose oneself to a fictional situation), the IRI measures empathic concern and personal distress. The former trait measures sympathy and compassion for less fortunate others (i.e., an other-oriented emotional reaction), whereas the latter measures the experience of discomfort in response to distress in others (i.e., a self-oriented emotional reaction). The difference between personal distress and empathic concern becomes clear when one looks at example items to measure personal distress – for example, "I tend to lose control during emergencies" and "When I see someone who badly needs help in an emergency, I go to pieces" – and empathic concern – for example, "I often have tender, concerned feelings for people less fortunate than me", "I am often quite touched by things that I see happen". In the literature, a variety of terms are used to describe an other-oriented emotional response to the distress of another person (C. D. Batson, 2009). *Empathic concern* and *sympathy*, the most commonly used labels in the literature, are often used interchangeably. The usage of the term *empathic concern* might however result in confusion, because it suggests that empathic concern and empathy are the same. Empathy refers to the multifaceted concept, while empathic concern is an aspect of this concept (Wispé, 1986). In line with the existing literature, we will use the term *sympathy* when referring to the trait measure of an other-oriented emotional reaction.

Procedure

The task and experimental procedure were identical for both experiments, unless otherwise specified. The experimental session started with six practice trials of the cued-reaction time task, using video clips of a woman standing and waiting. Next, participants completed a baseline block with the scrambled versions of videos used in the subsequent experimental blocks. In Experiment 1, only the two scenarios without bystanders were used in the main experimental blocks, whereas in Experiment 2, all six scenarios were used. No mention was made with respect to the content of the movies. Original and mirrored videos were included to prevent the possible influence of direction of movement in the videos (e.g., left motion direction) on the subsequent response. The stimuli were presented in a randomized order, and repeated twice, resulting in 24 go trials per condition. Participants were instructed to respond as quickly as possible with the index finger of their dominant hand and to fixate on the fixation cross shown continuously during the task. After the cued-reaction time task, participants completed the Dutch version of the IRI.

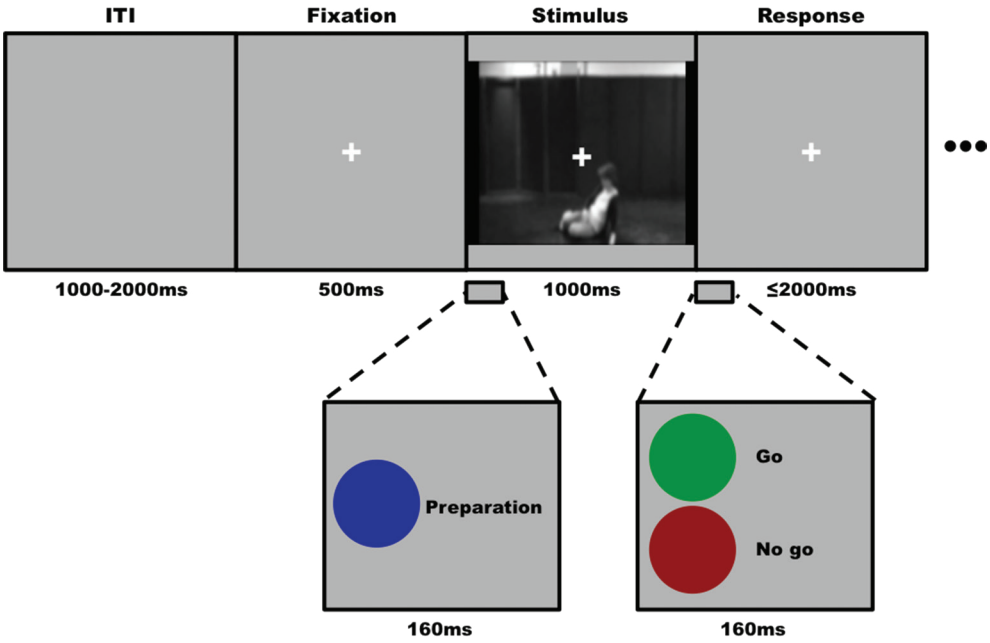


Figure 2. Cued-reaction time task. Between a preparation and a response cue, a video clip was shown. Participants responded as fast as possible to the go cue with the index finger of their dominant hand.

Data reduction and analysis

Reaction times below <150ms and >1500ms were removed from analysis (mean±*SD* percentage of trials removed: Exp. 1, 5.33±1.43 %; Exp. 2: 3.12±2.18 %), as well as incorrect trials (mean±*SD* percentage of false alarms and misses: Exp. 1: 2.30±2.48 %; Exp. 2: 2.27±2.17 %). Reaction times were calculated as percentage changes from the baseline (scrambled) block (set at 100 %).

In Experiment 1 a paired-sample t-test was performed to look at the difference in reaction times between an emergency and nonemergency situations. In addition, we subtracted the baseline-corrected reaction times of the nonemergency from those of the emergency trials to calculate a bias score, so that negative values indicated faster response to the emergency situation. In Experiment 2, a general linear model (GLM) for repeated measurements with situation (2) and number of bystanders (3) as within-subject factors was used to test the difference in influences of the number of bystanders on baseline-corrected reaction times during the observation of an emergency versus a nonemergency situation. Given the a priori predictions, we tested for a significant linear trend contrast. Paired-samples t-tests were used for the post-hoc testing.

To investigate the relationship between trait personal distress and sympathy and responses to an emergency, linear regression analyses were employed for both experiments. In the first

step, the hypothesized predictors were entered into the model (Exp. 1: trait personal distress and sympathy; Exp. 2: trait personal distress), whereas in Step 2, the remaining scales were added in a stepwise fashion (method: probability of F to enter <.05; criteria probability of F to remove >.1). Cohen's effect size (f^2) was calculated using the formula: $f^2 = R^2 / (1–R^2)$, with effect sizes of around 0.02, 0.15, and 0.35 being interpreted as small, medium, and large, respectively (Cohen, 1988). The alpha level of significance was set at .05 (two-tailed).

Results

Experiment 1

No difference in reaction times was found between emergency (mean±*SEM* percentage change from the baseline, 98.56±1.19 %) and nonemergency (99.13±1.18 %) situations, $t(29) = -0.44$, $p = .66$. A significant linear regression model was observed for the emergency-nonemergency bias score, $F(2, 27) = 13.16$, $p < .001$, $R^2 = .49$, $f^2 = .96$ (**Table 1**). In line with our expectations, participants with higher self-reported trait personal distress, $\beta = -.35$, $p = .02$, and sympathy, $\beta = -.54$, $p = .001$, responded faster to an emergency than to a nonemergency situation without bystanders (**Figure 3**).

Experiment 2

Table 2 shows the reaction times across conditions. No main effect for situation, $F(1, 29) = 3.69$, $p = .07$, or number of bystanders, $F(2, 58) = 0.40$, $p = .67$, was observed. Contrary to expectations, no significant interaction between situation and number of bystanders was found, $F(2, 58) = 1.43$, $p = .25$. The linear trend for this interaction was also not significant, $F(1, 29) = .99$, $p = .33$, indicating that the linear effect of the number of bystanders on reaction times did not vary as a function of the situation. To determine whether trait personal distress predicted the effect of an increase in the number of bystanders during an emergency situation, we calculated the regression slope of the reaction times as a function of the number of bystanders in each situation (emergency and nonemergency). This analysis was adapted from the perceptual-processing literature, in which the slope of the reaction times is calculated as a function of set size (for example Golan, Bentin, DeGutis, Robertson, & Harel, 2014; Lockhart et al., 2014; Wolfe & Horowitz, 2004). In the present study, the slope indicated the change in reaction times with an increasing number of bystanders, and fits with the previously used parametric approach on group influences (Hortensius & de Gelder, 2014), as well as the finding that the bystander effect grows larger as the number of bystanders increases (Fischer et al., 2011). If the number of bystanders has a disruptive effect on the perception of and reaction to an emergency, people would be slower when the number of bystanders increases, and thus reaction times will increase (positive slope). If, on the other hand, an increase in the number of bystanders has no effect, reaction times would not increase and the slope will be zero. Finally, a negative slope would indicate a decrease in reaction times: people

Table 1. Outcome of regression analysis for emergency – nonemergency bias score in Experiment 1

	b	β	*p*
Step 1			
Overall model: $F(2,27) = 13.16$, $p < .001$, $R^2 = .49$, $f^2 = .96$			
Constant	29.36±5.95 [17.15, 41.57]		<.001
Personal distress	-0.67±0.27 [-1.22, -0.12]	-.35	.02
Sympathy	-0.98±0.25 [-1.50, -0.46]	-.54	.001
Step 2			
Perspective taking*		.16	.29
Fantasy*		.09	.58

b = unstandardized coefficients±standard error [95% confidence intervals], β = standardized coefficient. * Removed predictors.

respond faster when the number of bystanders increases. A positive and negative slope may be indicative of a decreased or increased tendency for helping behavior, respectively. The current findings showed a positive slope in the emergency situation, mean±*SEM*, 0.48±0.21, and the nonemergency situation, 0.17±0.25[1]. These slopes were not significantly different from each other, $t(28) = 1.17$, $p = .25$. While the nonemergency slope did not differ, $t(29) = 0.67$, $p = .51$, the emergency slope was significantly larger than zero, $t(28) = 2.33$, $p = .03$.

A significant model was found for the emergency slope, $F(2, 26) = 4.18$, $p = .03$, $R^2 = .24$, $f^2 = .32$ (**Table 3**). While personal distress was positively associated with the slowing of reaction times with an increase in the number of bystanders, $\beta = 0.29$, $p = .11$, it was neither a significant nor the sole predictor in the model. The slope was predicted by perspective taking, $\beta = .46$, $p = .02$[2]. Interestingly, when responding to the emergency situation, people with higher levels of trait perspective taking showed a stronger effect of the number of bystanders. In other words, people with a disposition to adopt the perspectives of other people became slower when the number of bystanders increases during an emergency. In line with expectations,

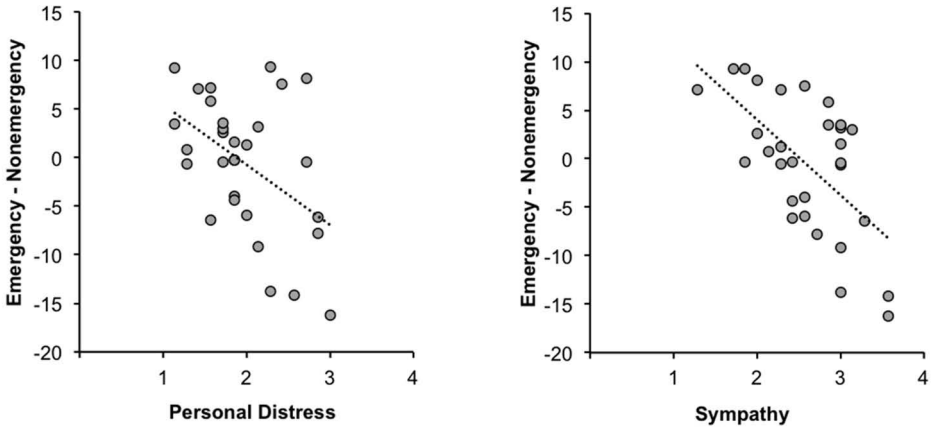


Figure 3. Trait personal distress and sympathy predicted faster responses to an emergency than to a nonemergency situation without bystanders.

Table 2. Mean reaction times ± standard errors in percentage changes from baseline for Experiment 2

	No bystanders	One bystander	Four bystanders
Emergency	86.34±2.14	87.83±2.13	87.86±1.91
Nonemergency	89.21±1.95	88.24±1.80	89.34±1.96

sympathy did not predict the influence of the number of bystanders, β =0 .11, p = .64. No significant model was found for the nonemergency slope, $F(1, 28) = 0.59$, p = .45, R^2 = .02.

Discussion

Consistent with our predictions, trait personal distress and sympathy were associated with faster responses to an emergency situation without bystanders present (Exp. 1). However, in contrast to our expectations, personal distress did not significantly predict the effect of the number of bystanders on reaction times during an emergency (Exp. 2). Perspective taking predicted slower responses to an emergency situation with an increase in the number of bystanders. This finding concurs with previous explanations of the bystander effect that appeal to a more cognitive level including diffusion of responsibility and pluralistic ignorance (Latané & Darley, 1970). Work by Clark and Word (1972) showed that the bystander effect is driven by ambiguity. Only during ambiguous situations was helping behavior reduced by the presence of bystanders. In the present experiment, the situation could be viewed as more ambiguous when there were more bystanders present. This bystander-induced ambiguity may have resulted in an increased need to evaluate the situation, the state of the woman, and the behavior of the bystanders, especially so for people with higher levels of trait perspective taking. The consequence of this is a slower response to the emergency situation.

Is this slowing in response the result of a slower response selection or increased top-down control of anticipatory responses? In the present cued-reaction time task, the preparation cue displayed before a go cue allows participants to already prepare their response and this can be influenced by the presented situation (emergency or nonemergency situation). Faster reaction times may thus be indicative of increased action preparation, whereas slower reaction times indicate a decrease in action preparation. While with a cued-reaction time task like the one used here, reaction times serve as a proxy for action preparation, the difficulty of using reaction times is in distinguishing between the preparation and execution of the

[1] One individual with a slope (-5.21) three standard deviations from the mean in the emergency situation was removed from the analyses. With this individual the slopes for the emergency (0.29±0.28) and nonemergency situation (0.11±0.25) where not significantly different from each other, $t(29) = 0.63$, p = .54 or from zero, $t(29) = 1.06$, p = .30 and $t(29) = 0.44$, p = .66 respectively.

[2] With inclusion of the outlier a significant model appeared, $F(2, 27) = 5.11$, p = .01, R^2 = .28, $f2$ = .39, in which personal distress, β = .38, p = .03, and perspective taking, β = .41, p = .02, predicted the emergency slope.

Table 3. Outcome of regression analysis for emergency slope in Experiment 2

	b	β	*p*
Step 1			
Overall model: $F(1,27) = 1.19$, $p = .29$, $R^2 = .04$			
Constant	-0.19±0.65 [-1.52, 1.15]		.78
Personal distress	0.34±0.31[-0.30, 0.98]	.21	.29
Step 2			
Overall model: $F(2,26) = 4.18$, $p = .03$, $R^2 = .24$, $f^2 = .32$			
Constant	-3.07±1.24 [-5.62, -0.51]		.02
Personal distress	0.48±0.29 [-0.11, 1.07]	.29	.11
Perspective taking	0.96±0.36 [0.21, 1.71]	.46	.01
Sympathy*		-.11	.64
Fantasy*		-.006	.98

b = unstandardized coefficients ± standard error [95% confidence intervals], β = standardized coefficient. * Removed predictors.

response. Moreover, contextual effects on reaction times can be driven by perceptual or action processes or a combination of both. One way to overcome this issue is to directly target the human primary motor cortex by means of transcranial magnetic stimulation (TMS). Using this technique, a noninvasive magnetic pulse is delivered at the surface of the scalp overlying the primary motor cortex. This pulse results in a current flow in the cortex and produces a motor-evoked potential (MEP). Motor corticospinal excitability can be quantified by MEP amplitude. Single-pulse TMS to map motor corticospinal excitability levels when individuals observe a social cue has been used in the study of action observation (Avenanti, Candidi, & Urgesi, 2013; Fadiga et al., 1995), emotion (Hajcak et al., 2007; Schutter et al., 2008b), and empathy (Hétu, Taschereau-Dumouchel, & Jackson, 2012). Importantly, increases in MEP amplitude has been proposed to index action preparation (Coombes et al., 2009; Hajcak et al., 2007; Schutter et al., 2008b; van Loon et al., 2010).

In the third experiment we used single-pulse TMS to measure changes in motor corticospinal excitability levels to further substantiate the influence of personal distress. By probing the primary motor cortex of healthy individuals we aimed to extend the previous experiments by directly quantifying changes in the motor system as a function of the number of bystanders during an emergency situation. TMS studies have shown that when confronted with pain in another individual, both state and trait measures of personal distress increase, rather than decrease, motor corticospinal excitability in the onlooker (Avenanti, Minio-Paluello, Sforza, & Aglioti, 2009). Moreover, trait personal distress has been positively correlated with higher motor corticospinal excitability levels in response to viewing negative valenced pictures (Borgomaneri, Gazzola, & Avenanti, 2014a). These results suggest that a disposition to experience distress can have a direct influence on perception and action. Indeed, a recent study using kinematics showed that trait personal distress predicted reduced motor control in participants who were confronted with another person's negative emotions (Ferri et al.,

2010). In line with these findings, we expected that the linear decrease in motor corticospinal excitability levels as a function of increasing number of bystanders during an emergency would be predicted by personal distress.

Interestingly, previous studies have observed a relationship between trait levels of perspective taking and motor corticospinal excitability levels (Avenanti et al., 2009; Borgomaneri, Gazzola, & Avenanti, 2014b). These findings were opposite to the pattern found for personal distress and interpreted as simulation of the (action) state of the observed individual and not action preparation. While we do not foresee an effect of perspective taking, these observations suggest that if perspective taking is predictive of the influence of bystanders on responding to an emergency it will be opposite to the pattern found for personal distress.

Experiment 3

Methods

Participants

Twenty-three right-handed volunteers (19 women, four men), between 19 and 27 years of age, participated in the experiment in exchange for course credits or payment. Participants were screened for contraindications for non-invasive brain stimulation (Keel et al., 2001). None of the volunteers had a history of psychiatric or neurological disease, and all had normal or corrected-to-normal vision. The participants were naïve as to the aim of the study, and written informed consent was obtained. The study was approved by the medical ethics committee of the University Medical Center Utrecht and Utrecht University, Utrecht, The Netherlands. Stimulation parameters were in agreement with the International Federation of Clinical Neurophysiology safety guidelines (Rossi et al., 2009) and in accordance with the standards set by the Declaration of Helsinki.

Transcranial magnetic stimulation

A biphasic magnetic brain stimulator (maximum output 4,160 A peak/1,750 VAC peak) with a modified 8-shaped iron core coil (Neopulse, Atlanta, GA, USA) was used for stimulation over the left M1.

Motor Evoked Potentials

Motor evoked potentials were recorded with active Ag-AgCl electrodes (11 x 17mm) using an ActiveTwo system (BioSemi, Amsterdam, the Netherlands) from the right abductor pollicis brevis (APB) in a belly-tendon montage with the active electrode placed at the muscle belly of the right APB and the reference electrode located at the proximal phalanx of the thumb (Baumgartner et al., 2007; Hajcak et al., 2007; Schutter et al., 2008b). The ground (CMS-

DRL) electrode was attached to the wrist. The sampling rate was set at 2048 Hz, and the signal was offline high-pass filtered (3dB cutoff frequency: 20Hz, roll-off 24dB/dB/octave).

Procedure

Upon arrival at the laboratory, the experimenter explained the procedure, and participants provided written informed consent and answered several questions on present physical and mental well-being. Participants were seated in a comfortable dentist chair, with their arms placed on the upper leg and the palm of the hand facing upward. The resting motor threshold (MT) of the left hemisphere was assessed by means of the standardized visual thumb movement procedure (Schutter & van Honk, 2006). During the task, TMS intensity was set at 120% MT. Participants were instructed to relax their body and not to focus on their hands, but to fixate on the fixation cross shown continuously during the task. Participants did not need to respond during stimulus presentation. The same stimuli as used in Experiment 2 were presented in random order, with a blank screen with a fixation cross (4800–5200ms) in between. Thus, six conditions were used, with the situation (emergency versus nonemergency) and the number of bystanders (none, one or four bystanders) as within-subjects factors. As in the previous two experiments, no mention was made with respect to the content of the movies. The TMS pulse was pseudorandomly delivered between 800 and 1,000ms (in six steps of 40ms) after stimulus onset. This procedure is commonly used in single-pulse TMS studies to prevent anticipation by the participants (for example Avenanti et al., 2005). In the present study, the timing of the pulse did not affect MEP amplitudes, as shown by a general linear model (GLM) for repeated measurements with timing of pulse (6) as within-subject factors, $F(5, 100) = 0.82$, $p = .51$. **Figure 4** shows the TMS procedure. Similar to Experiments 1 and 2, the procedure started with three practice trials (woman standing and waiting), followed by the scrambled videos of the scenarios serving as the baseline (12 trials) and lastly, random presentation of the six scenarios (12 trials per condition). As in the previous two experiments, participants completed the IRI at the end of the experiment. Upon completion, participants were debriefed and received payment.

Data analysis

The data from one participant were removed because of noisy and unstable EMG signal, and data from a second participant was removed because of failure to comply with instructions (i.e., excessive movement during testing). MEP was quantified as the peak-to-peak amplitude of the maximal EMG response. Every trial was visually inspected, and this was done blind to the stimulus condition. Trials containing excessive background EMG and abnormal MEPs were removed. Mean±*SD* percentage of trials removed across the participants was 4.37±4.15 %. MEP amplitudes were calculated as percentage change from MEP amplitude during the baseline (scrambled) block.

For the statistical analyses a similar procedure to that described in Experiment 2 was followed. First, to test the influence of the number of bystanders on MEP amplitude during

the observation of an emergency versus a nonemergency, a general linear model (GLM) for repeated measurements with situation (2) and number of bystanders (3) as within-subject factors was used.

Next, we calculated the slope of the MEP amplitude with the increase in the number of bystanders for the emergency and nonemergency situations for each individual. A negative slope would indicate that MEP amplitude decreased as a function of the number of bystanders. A decrease in MEP amplitude reflects a decrease in action preparation, and an increase would reflect an increase in action preparation. To examine the relation between trait personal distress and the effect of the number of bystanders on MEP amplitude, a similar linear regression analysis was employed as in Experiment 2. Trait personal distress was entered in the first step, while in step two the three other trait empathy scores were added to the model in a stepwise fashion. Trait empathy scores of one participant were missing, resulting in a sample of 20 participants for the regression analyses.

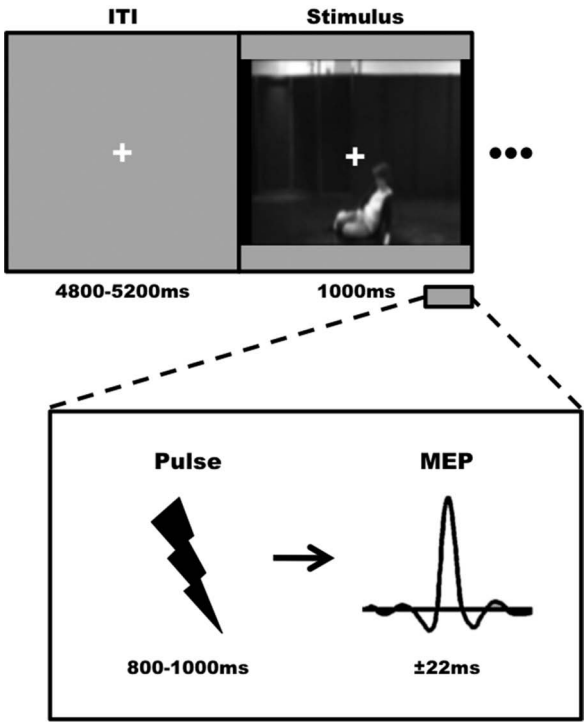


Figure 4 Transcranial magnetic stimulation (TMS) task. Motor-evoked potentials (MEP) were recorded to a TMS pulse that was pseudorandomly delivered between 800 and 1,000ms after video clip onset.

Results

TMS was well tolerated and no adverse events occurred. **Table 4** shows the MEP amplitude across conditions. No main effect for situation, $F(1, 20) = 0.97$, $p = .34$, number of bystanders, $F(2, 40) = 0.54$, $p = .59$, or interaction between situation and number of bystanders, $F(2, 40) = 0.30$, $p = .74$, were found. Additionally, we tested if trait personal distress predicted the effect of the increase in the number of bystanders on motor corticospinal excitability levels during an emergency. A significant linear regression model was observed for the emergency slope, $F(1,17) = 5.42$, $p = .03$, $R^2 = .24$, $f^2 = .32$ (**Table 5**). In line with the expectations, personal distress was negatively related to the effect of the number of bystanders during an emergency on motor corticospinal excitability level, $\beta = -.49$, $p = .03$[3]. No significant model emerged for the nonemergency slope, $F(1, 19) = 0.77$, $p = .39$, $R^2 = .04$.

Discussion

In the third experiment, we examined the effect of the number of bystanders during an emergency situation on a direct measure of the motor system using single-pulse TMS. No linear decrease in motor corticospinal excitability levels was observed with an increasing number of bystanders when participants witnessed an emergency. In line with our expectations, people with higher levels of personal distress showed a stronger decrease in motor corticospinal excitability levels during the observation of an emergency when the number of bystanders increased.

In the previous two experiments we observed that both personal distress and perspective taking are associated with the effect of the number of bystanders on responding to an emergency. Using a direct measure of the physiological state of the motor system we found that only personal distress and not sympathy or perspective taking predicted the effect of the number of bystanders. These results suggest that the effect of bystanders on the initial response to an emergency may be indeed related to action preparation (Hortensius & de Gelder, 2014). To further quantify this relation between personal distress and the effect of bystanders and to disentangle the influence of perspective taking and personal distress on action preparation, we studied the influence of automaticity and cognitive involvement on these processes in a final experiment.

Several studies have started to explore if reactions to distressful events are automatic (for

[3] As in Experiment 1 and 2, we checked for outliers. In line with Cook and Weisberg (1982), we removed one individual with Cook's distance of 1.39. With this individual included, a similar, but weaker, model appeared, $F(1, 18) = 3.72$, $p = .07$, $R^2 = .17$, $f2 = .20$, in which personal distress predicted the emergency slope, $\beta = -.41$, $p = .07$.

Table 4. Mean motor-evoked potential amplitudes ± standard errors in percentage changes from baseline for Experiment 3

	No bystanders	One bystander	Four bystanders
Emergency	133.94±14.06	142.39±14.72	140.18±14.33
Nonemergency	133.32±11.68	133.35±14.55	134.74±14.47

example Gu & Han, 2007; Morelli & Lieberman, 2013; Rameson et al., 2012; Yamada & Decety, 2009). For example, Rand and Epstein (2014) showed that the decision making process for extreme altruistic acts can be described as fast, intuitive and reflexive. Of course, it is not an all or nothing mechanism. Some aspects of an empathic reaction can be automatic and reflexive, while others are deliberate and reflective in nature. Fan and Han (2008) showed that late, but not early components are influenced by task manipulation. Moreover, inter-individual differences in terms of automaticity and attentional malleability of empathic responses have been reported (Rameson et al., 2012). Individuals with higher levels of trait empathy showed no reduction in empathic responses when performing an unrelated task, suggesting a more automatic process underlying these responses in these individuals. However, this study did not look at different aspects of empathy.

While sympathy and personal distress are both considered to be part of a larger affective empathy cluster, they rather differ in terms of cognitive involvement. While conditioning, direct association, and simple labeling or categorization of the emergency can lead to personal distress, they do not lead to feelings of sympathy (Eisenberg, Shea, Carlo, & Knight, 2014). Personal distress requires minimal cognitive processes (Eisenberg et al., 2014; Eisenberg & Fabes, 1990), whereas sympathy requires more elaborate or more complex cognitive processes. Similarly, perspective taking, the capacity to understand the thoughts and feelings of another individual (M. H. Davis, 1980) requires more sophisticated, top-down processes (M. H. Davis, Conklin, Smith, & Luce, 1996). This dissociation between personal distress, and sympathy and perspective taking, is also reflected in relations with prefrontal functions (Spinella, 2005). Trait personal distress was related to more executive dysfunction, while perspective taking

Table 5. Outcome of regression analysis for the emergency slope in Experiment 3

	b	β	*p*
Step 1			
Overall model: $F(1,17) = 5.42$, $p = .03$, $R^2 = .24$, $f^2 = 0.32$			
Constant	14.22±5.69 [2.22, 26.22]		.02
Personal distress	-1.32±0.57 [-2.52, -0.12]	-.49	.03
Step 2			
Sympathy*		-.15	.54
Perspective taking*		.18	.42
Fantasy*		.25	.26

b = unstandardized coefficients ± standard error [95% confidence intervals], β = standardized coefficient. * Removed predictors.

and sympathy were inversely related to executive dysfunction.

One possible way to disentangle the influence and need of cognitive processes on personal distress, sympathy and perspective taking and the possible automaticity of these reactions is the use of a cognitive load manipulation. By imposing a cognitive load during the occurrence of another task, the dynamics between cognitive processes and the behavior of interest can be established. Under low load conditions, the cognitive system is accessible and can influence behavior. This behavior can be described as being reflective, deliberate or explicit. Under high load conditions the cognitive system is engaged and relatively inaccessible. If a particular behavior occurs during a high cognitive load manipulation it is indicative of an automatic or reflexive mechanism (Gilbert, Pelham, & Krull, 1988), as these processes are not dependent on cognition.

By using a cognitive load manipulation during the cued-reaction time task, we aimed to extend the previous findings and to dissociate the influence of trait perspective taking and personal distress on the negative influence of bystanders. Given the foregoing it was hypothesized that under conditions of high cognitive load, only trait personal distress would predict the slowing of reaction times during an emergency with bystanders present. If trait perspective taking would be related to an effect of bystanders, this would only be apparent under conditions of low cognitive load. In line with the previous findings, we expect that sympathy does not predict an effect of bystanders during the observation of an emergency either in the low or high cognitive load condition.

Experiment 4

Methods

Participants

Thirty-nine female and eleven male volunteers (43 right-handed, 6 left-handed, 1 ambidextrous), between 18 and 28 years of age, participated in exchange for course credits. Participants were naïve as to the aim of the study, provide informed consent, and the experiment was carried out in accordance with the standards set by the Declaration of Helsinki.

Task and Procedure

The cued-reaction time task was adapted slightly to allow a cognitive load manipulation. Participants were instructed to remember a two-digit number (e.g., 12, low cognitive load) or a combination of three two-digit numbers (e.g., 24, 36, 87, high cognitive load) while performing the cued-reaction time task. Before each block of the cued-reaction time task a

screen with a load instruction was presented to the participant for 2,500 ms. This was followed by a block of 8 reaction time trials with 25% no go trials. After each block a memory probe was shown and participants indicated which of the two numbers was part of the original sequence.

At the start of the experimental session, participants first practiced the cued-reaction time in isolation (3 trials), followed by two practice blocks with the cognitive load manipulation (one low and one high cognitive load block each with three reaction time trials). Participants were instructed to remember the number presented at the start of each block, while simultaneously performing the cued-reaction time task. For the practice trials video clips of a woman standing and waiting were used, while for the main experimental blocks only the emergency and nonemergency scenarios with no and four bystanders were used. In the first half of the experiment only the emergency and nonemergency situations with no bystanders were shown followed by the emergency and nonemergency situation with bystanders present. This was done to first measure the initial response to an emergency without bystanders and subsequently assess the impact of bystanders on the response to an emergency without trial-to-trial fluctuations and across-trial influence (cf Rameson et al., 2012). The cognitive load manipulation was presented in a randomized order throughout the experiment, while the emergency and nonemergency situations were presented in a randomized order within each block. In total there were 32 blocks, resulting in 24 go trials per condition. After the cued-reaction time task, participants completed the Dutch version of the IRI.

Data analysis

Cognitive load manipulation was successful and accuracy decreased in the high cognitive load condition (mean±SD percentage correct: 86.50±11.11 %), compared to the low cognitive load condition (92.13±11.97 %), $t(49) = 3.41$, $p = .001$, d = 0.48. Filtering of the reaction times was similar to Experiment 1 and 2 (mean±SD percentage of trials removed: 0.63±0.96 %, mean±SD percentage of false alarms and misses: 2.94±2.26 %). To calculate a bias score, we subtracted the reaction times of the situation with bystanders present from the reaction times in situations with no bystanders present, individually for the emergency and nonemergency situation in both low and high cognitive load conditions. Negative values indicated slower responses to the situation with bystanders present, thus a stronger bystander effect, while positive values indicate faster responses to the situations with bystanders present. Next, we corrected for general task effects by performing a regression that predicted the bias scores in each of four conditions on the basis of the task effect (accuracy low - high cognitive load). By using the standardized residual of each of the bias scores, the variance explained by overall task performance is removed and the unique contributions of each condition can be examined. Next, linear regression analyses were used to predict the bias scores for the emergency and nonemergency situation under conditions of low and high cognitive load. Similar to the previous experiments, in the first step the hypothesized predictors were entered into the model (low cognitive load: trait perspective taking, high cognitive load: trait personal

distress), while the remaining scales were added in step 2 (stepwise fashion).

Results

In the low cognitive load condition no significant linear regression model was found for the emergency, $F(1, 48) = 0.98$, $p = .33$, $R^2 = .02$, or nonemergency situation, $F(2, 47) = 2.58$, $p = .09$, $R^2 = .10$. In the high cognitive load condition a significant linear regression model was observed for the emergency, $F(1,48) = 6.02$, $p = .02$, $R^2 = .11$, $f^2 = 0.12$ (**Table 6**), but not for the nonemergency situation, $F(1, 48) = 1.53$, $p = .22$, $R^2 = .03$. Crucially, trait personal distress predicted a stronger slowing of responses to an emergency situation with bystanders compared to no bystander present, $\beta = -.33$, $p = .02$ (**Figure 5)**. Nor sympathy nor perspective taking predicted the effect of bystanders, $\beta = -.12$, $p = .44$ and $\beta = .09$, $p = .52$ respectively.

Discussion

In our final experiment, we used the cued-reaction time task combined with a cognitive load manipulation to influence cognitive involvement during the observation of an emergency with bystanders present. In agreement with our expectations, results showed that personal distress predicted the slowing of responses to an emergency with bystanders present during the high cognitive load condition. In other words, people with higher levels of personal distress demonstrated stronger response slowing to an emergency with bystanders present when cognitive involvement was restricted. Under conditions of low cognitive load, thus without cognitive restriction, neither personal distress nor perspective taking akin predicted

Table 6. Outcome of regression analysis for the no bystander − bystander bias score in the emergency situation with high cognitive load in Experiment 4

	B	β	*p*
Step 1			
Overall model: $F(1,48) = 6.02$, $p = .02$, $R^2 = .11$, $f^2 = 0.12$			
Constant	0.99±0.42 [0.14, 1.84]		.02
Personal distress	-0.53±0.22 [-0.97, -0.10]	-.33	.02
Step 2			
Sympathy*		-.12	.44
Perspective taking*		.09	.52
Fantasy*		-.22	.14

b = unstandardized coefficients ± standard error [95% confidence intervals], β = standardized coefficient. * Removed predictors.

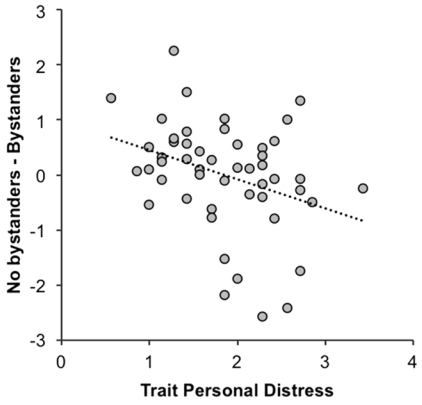


Figure 5. Under high cognitive load trait personal distress predicted the slowing of responses when bystanders were present during an emergency.

an effect of bystanders on responding to an emergency. Sympathy was not associated with an effect of bystanders on responses to an emergency either in the presence or absence of cognitive restriction. The results of Experiment 3 indicated that personal distress is predictive of a mechanism related to action preparation, and the results of Experiment 4 extend these findings in an important manner. Personal distress predicted an effect of bystanders on an initial response to an emergency that is more related to automatic, reflexive action preparation.

General Discussion

The aim of the present study was to investigate the influence of bystanders on the response of an individual to an emergency situation by integrating situational and dispositional factors. In a series of four experiments we examined the differential effects of trait sympathy and personal distress on the decrease in preparation to help with bystanders present. Results showed that even though personal distress and sympathy predicted overall faster responses to an emergency when no bystanders were present, personal distress was most consistently predictive of a decrease in action preparation when bystanders are present during an emergency. These results are in line with findings showing differences between other-oriented and self-centered responses to emergency situations in terms of sensitivity to social context. These observations show that the effect of bystanders is already apparent at the level of action preparation. This bystander effect is proposed to be stronger for people with a predisposition to experience self-centered empathic responses, as measured by trait personal distress.

Our observations add to the growing body of evidence on how empathic responses are modulated by situational and dispositional factors (Decety & Lamm, 2009), as well as how

sympathy and personal distress differ in sensitivity to social context (Archer et al., 1981; C. D. Batson et al., 1981; 1983; 1987; Carlo et al., 1991; Coke et al., 1978; Eisenberg, Fabes, et al., 1989a; Fultz et al., 1986; Romer et al., 1986; Toi & Batson, 1982). Decety and Jackson (2004) argue that three inter-related mechanisms underlie the variety of empathic responses; perception-action coupling (see also Preston & de Waal, 2002), emotion regulation mechanisms, and perspective taking. Since trait personal distress as well as sympathy measure affective responses to the distress of others (M. H. Davis, 1983), one possibility is that a disposition to experience and regulate negative emotions (Davidov, Zahn Waxler, Roth Hanania, & Knafo, 2013), underlie this difference in sensitivity to social context. Studies have shown a positive relation between a disposition to experience personal distress and heightened behavioral and physiological responses to social emotional situations and decreased regulation of these responses (Avenanti et al., 2009; Borgomaneri, Gazzola, & Avenanti, 2014a; Eisenberg & Fabes, 1990; Eisenberg et al., 1994; Ferri et al., 2010; Okun, Shepard, & Eisenberg, 2000). In contrast, trait levels of sympathy have been linked to increased emotion regulation (Eisenberg et al., 1996; Okun et al., 2000). Using single-pulse TMS we show that personal distress but not sympathy predicts the negative influence of bystanders on motor corticospinal excitability levels as indexed by MEPs. In line with previous studies (Avenanti et al., 2009; Borgomaneri, Gazzola, & Avenanti, 2014a; Ferri et al., 2010), these results suggest that a distinction between sympathy and personal distress can be observed already in the action-domain. A disposition to experience personal distress compared to sympathy can thus not only lead to an imbalance in higher, regulatory-related processes, but may already have an influence at a lower , action-related processes. Although the default mode is to help – that is, intact coupling between situation and response – the presence of bystanders may result in a decoupling. This effect may be stronger in people with higher levels of personal distress who display attenuated action preparation to respond to the emergency situation in the presence of bystanders.

What could drive this decoupling? The perception-action arc is motivation-dependent (Carver, 2006; Mogenson, Jones, & Yim, 1980). The state of the motor cortex (Schutter, de Weijer, Meuwese, Morgan, & van Honk, 2008a; Schutter, Hofman, Hoppenbrouwers, & Kenemans, 2011), as well as the multifaceted concept of empathy (Gutsell & Inzlicht, 2012; Tullett, Harmon-Jones, & Inzlicht, 2012; Zaki, 2014) have been linked to approach and avoidance-related motivation. As described by Preston (2013), the distinction between avoidance and approach is crucial in explaining the lack of helping behavior in some situations. To respond to an emergency, the event has to be classified as a threat, which consequently triggers approach- or avoidance-related behavior. There are several explicit or implicit strategies that can result in approach or avoidance of current or future empathic responses (Zaki, 2014). For example, the avoidance can be overt (need to escape the situation) or covert (attentional disengagement). Graziano and Robin (2009) describe the approach/avoidance dimension of an emergency situation. They suggest that two evolutionary conserved motivational systems, fight-or-flight, including freezing behavior (flight-freeze-flight system; for example N. McNaughton & Corr, 2004), and parental care, are activated

when encountering a novel or distressful event and these two systems act as opponents to each other's dominant action patterns. Incorporating the opponent-process model of motivation by Solomon and colleagues (Solomon, 1980; Solomon & Corbit, 1974), the authors state that the first, and fastest, response to an emergency is that of distress (Process A, fight-freeze-flight system), and if the possibility to escape the situation is available and easy, helping behavior does not occur. However, over time the slower reaction of sympathy (Process B, care system) is activated opposing the fixed action patterns of personal distress (W. G. Graziano & Habashi, 2010; W. G. Graziano & Tobin, 2009). This nicely fits the observation in the first experiment that, while sympathy and personal distress are opposing constructs, they both predicted faster responses to an emergency without bystanders present, and the notion in the literature that they are positively correlated and can exist in parallel within an individual (C. D. Batson et al., 1987; M. H. Davis, 1980). However, the presence of bystanders during an emergency possibly increases Process A (distress, the fight-freeze-flight system), leading to heightened distress and mitigating preparation of helping behavior, while Process B (sympathy, care system) is not afflicted by the presence of bystanders. This bystander-mediated increase in distress in the observer and increased activation of the fight-freeze-flight system is only apparent in people with a disposition to experience personal distress. However, it remains unknown if and how this increase in state levels of distress occurs and what the dynamics of a personal distress state-trait interaction are.

It is possible that the observed effect might not be related to a decrease in action preparation or inhibition of approach, but rather to a freeze-like response. This amounts to a reduction in motor corticospinal excitability with the increase in the number of bystanders during an emergency. Thus, this reduction might reflect increased freezing in people with a disposition to experience personal distress. Freezing occurs when there is no possibility to escape the situation (or predator), or as an initial phase in a response (N. McNaughton & Corr, 2004). Several arguments complicate the interpretation of the decrease in motor corticospinal excitability as a freezing motor plan. First, a freeze-like reduction in motor corticospinal excitability has been recorded 100-125ms post-stimulus onset (Borgomaneri et al., 2015b). In the present study we stimulated in a time window 800-1,000ms post-stimulus onset, making it unlikely that we tapped into a freeze-like motor program. Second, both state and trait levels of personal distress are related to enhanced motor corticospinal excitability to stimuli negative in valence that are contrary to a freeze-related reductions in excitability levels (Avenanti et al., 2009; Borgomaneri, Gazzola, & Avenanti, 2014a). Third, we measured MEPs from an extensor muscle, the abductor pollicis brevis. While the link between extensor and flexor muscles and approach and avoidance motivation is complicated (Krieglmeyer & Deutsch, 2013; Phaf, Mohr, Rotteveel, & Wicherts, 2014), recordings of abductor pollicis brevis and other muscles have been linked to approach motivation (Coombes et al., 2009; Schutter et al., 2008b). To shed more light on the issues of approach and avoidance motives, future studies may incorporate different TMS procedures that allow the measurement of inhibitory processes, recordings from multiple muscle groups at several time periods, and

more direct measures of freezing, motivation and prosocial behavior to disentangle these different processes. In addition, future research can use different situations (e.g., a person directly being threatened by another individual with bystanders present) to shed light on motives in the onlooker.

Helping behavior is thought to be driven by an evolutionarily conserved mechanism, reflexive in nature (Preston, 2013) and shared with other species (Preston & de Waal, 2002), that is the end result of bottom-up and top-down processes. This is not to say that the decoupling is a deliberate, cognition-driven process, In the final experiment personal distress predicted the effect of bystanders on responding to an emergency under conditions of high cognitive load. This suggests that the bystander effect is not only apparent at an explicit cognitive level, but also on an implicit automatic action-related one. The perception-reaction arc can be automatic but still be context-dependent (Gawronski & Cesario, 2013). While some research suggest that the perception of and reaction to the need of others is not automatic (for example Gu & Han, 2007; Rameson et al., 2012), it is important to note that the majority of studies focused on the perception of the need and distress of others. In the present study we highlight the reactive aspect by measuring reaction times and motor corticospinal excitability to the distress of others. In contrast with other studies that tend to be biased towards explicit cognitive processes (intention, mental states), we focus on perception-action coupling as a function of context.

In the second experiment we observed that perspective taking and not personal distress predicted the negative effect of bystanders on responding to an emergency. What is the role of perspective taking? How does this relate to the effect of personal distress and the two system perspective? Multiple mechanisms can exist in parallel to influence responses to, and helping behavior during, an emergency situation with bystanders. The prosocial individual is the combined sum of situational-dependent cognition (e,g, perspective taking), feelings (e.g., personal distress or sympathy), and behavior (Habashi & Graziano, 2015). Of course these components interact. Perspective taking can lead to an increase in state sympathy (C. D. Batson et al., 1989; C. D. Batson, Dyck, Brandt, & Batson, 1988; Toi & Batson, 1982). For example, instructing participants to take the perspective of the victim rather than simply observe the victim increases sympathy, while personal distress remains unchanged (Toi & Batson, 1982). These interactions are also found for trait levels. Perspective taking is positively correlated with sympathy, but negative correlated with personal distress (M. H. Davis, 1980; De Corte et al., 2007). One hypothesis that partly reconciles the results is that perspective taking, by means of its interaction with sympathy, is related to Process B (sympathy, care system). While Process B is not influenced directly by the presence of bystanders, it is by means of perspective taking. The latter would sustain a form of cognitive influence on Process B. Together, situational influences on both Process A and B might be mediated by trait levels of personal distress and perspective taking respectively. How the slowing of responses as predicted by perspective taking is related to helping behavior remains to be investigated.

The majority of participants were female college students, and the question arises whether the present findings can be generalized to the population at large. Popular believe holds that women score higher on empathy-related constructs, but men are more likely to provide help. So far, no consistent sex differences in helping behavior have been reported (Eagly & Crowley, 1986). In a recent meta-analysis using all studies on the bystander effect between 1960 and 2010, no significant sex difference was found (Fischer et al., 2011). Importantly, Tice and Baumeister (1985) showed that sex or the level of femininity did not influence the occurrence of helping behavior when bystanders were present. Only participants high in masculinity provided less help. It has been argued that sex differences in helping behavior (and other empathy-related processes) are all about gender roles (Eagly & Crowley, 1986; Senneker & Hendrick, 1983). These differences only emerge when gender roles are primed by means of social context, such as demand characteristics and type of helping behavior studied, and are motivation-dependent (Eisenberg & Lennon, 1983; Ickes, Gesn, & Graham, 2000; K. J. K. Klein & Hodges, 2001). Although sex differences or the impact of gender roles on the processing of an emergency and helping behavior were not part of our primary research question, they can be of interest for future research.

Another issue with both methodological and theoretical consequences that could be addressed in future research is the effect of repetition on responses to emergency situations with or without bystanders. Of course, a certain number of trials is necessary to achieve a reliable measure of response time, but it might also have several important consequences. First, reaction times might change as a function of repetition number. While the effect of repetition on stimulus-response relationships have been studied (Bertelson, 1965; Felfoldy, 1974) the interaction with stimulus condition and personality characteristics remain unknown. How do multiple repetitions of an emergency situation interact with a disposition to experience personal distress? Based on the application of the model described by Graziano and Robin (2009) on the current data, repetition could have differential effects on Process A (distress, the fight-freeze-flight system) and Process B (sympathy, care system). One hypothesis conceptually driven by the work of Solomon and colleagues (Solomon, 1980; Solomon & Corbit, 1974) suggests that with increased repetition or exposure to emergencies the dominance of Process A diminishes, while Process B increases in strength (W. G. Graziano & Habashi, 2010). This would then result in a decrease in distress-driven processes and an increase in sympathy-driven processes. In the present context, one would thus expect that with an increase in repetition personal distress will eventually not be predictive of the negative effect of bystanders on responding to an emergency. However, repetition effects can take multiple forms and shapes (Grill-Spector, Henson, & Martin, 2006) and the interaction with stimulus condition and dispositional factors need to be investigated in carefully designed experiments.

In conclusion, using a person-situation approach we have extended the existing literature on the psychological and neural basis of the bystander effect by showing that the presence of bystanders during an emergency attenuates action preparation for people with higher levels

of trait personal distress –that is, with a disposition to experience self-centered empathic responses.

Chapter 7

Predicting helping behavior during a violent conflict using behavioral reactivity

Abstract

Informed by naturalistic observations, experimental findings, and theoretical models of functional altruism and prosocial behavior, we studied if inter-individual differences in reflexive- and reflective-like processes serve as a proximate mechanism and are predictive of prosocial behavior. We used behavioral reactivity, self-reported decision-making, proxemics behavior, and Immersive Virtual Reality to study helping behavior during a violent conflict. Specifically, we used behavioral responses to an emergency under conditions of cognitive restriction to predict later helping behavior during this conflict. First, 29 male supporters of F.C. Barcelona performed a cued-reaction time task with a low and high cognitive load manipulation. Next, participants entered a virtual bar and had a conversation with a fellow supporter. During this conversation a Real Madrid supporter entered and started a verbal fight with the fellow supporter that escalated into a physical fight. Verbal and physical interventions of the participant served as measures of helping behavior. In contrast to the hypothesis, results showed that faster responses to an emergency situation during low but not during high cognitive load, predicted more interventions during the violent conflict. In addition, a tendency to describe the decision-making during the violent conflict as intuitive, reflex-like was related to more interventions. Exploratory analyses revealed that a disposition to experience other-oriented feelings during distress was related to self-reported intuitive decision-making and helping behavior by proxy, that is a reduced distance to the perpetrator. Taken together, these results shed new light on helping behavior and are in line with a dual-process, sequential opponent motivational system.

Introduction

Helping behavior is not something uniquely human. Functional altruism and socially motivated helping, behaviors that benefit the recipient but with a cost to the actor, are observed throughout the animal kingdom (de Waal, 2015). Humans as young as 12 to 14 months provide help (Liszkowski, Carpenter, Striano, & Tomasello, 2006; Warneken et al., 2007; Warneken & Tomasello, 2006). Chimpanzees demonstrate costly helping in a variety of situations with and without reward (Warneken et al., 2007; Warneken & Tomasello, 2006; Yamamoto, Humle, & Tanaka, 2009; 2012). There is considerable evidence that rats exhibit helping behavior (Ben-Ami Bartal et al., 2011; 2014; Church, 1959; Márquez et al., 2015; Rice & Gainer, 1962; Sato et al., 2015). Moreover, observations point to the existence of functional altruism in ants (Hollis & Nowbahari, 2013; Nowbahari & Hollis, 2014; Nowbahari, Scohier, Durand, & Hollis, 2009). While the debate is ongoing whether all of these costly behaviors can be interpreted as a form of empathy (Silberberg et al., 2014; Vasconcelos, Hollis, Nowbahari, & Kacelnik, 2012), the crucial point is the occurrence of helping behavior. The fact that helping behavior is so widespread suggests the presence, at least at some level, of a phylogenetically ancient mechanism that gives rise to the variety of prosocial and empathic behaviors in humans (Decety et al., 2012; Preston & de Waal, 2002). Indeed, recent theoretical models point to offspring care (Preston, 2013) as a possible hard-wired, evolutionarily conserved mechanism that could provide the foundation for helping behavior and other functional altruistic behaviors. Importantly, as the species that show helping behavior differ greatly in cognitive capacities, it is unlikely that these capacities play a crucial role in the preparation and execution of helping behavior. Thus, the occurrence of helping behavior is likely to be relatively independent from cognition and to rely more on automatically triggered fixed-action patterns (Preston, 2013; Zaki, 2014).

Is providing help a reflexive action? Statements on the decision to act given by people that provided help under extreme circumstances are rated as automatic, reflex-like, rather than deliberate or reflective (Rand & Epstein, 2014). Studies directly manipulating decision time found that under time pressure people are more cooperative as a results of a more intuitive decision-making process (Cone & Rand, 2014; Rand, Greene, & Nowak, 2012; Rand et al., 2014). Time pressure also increased reported inclination to sacrifice a preferred activity to help a close other (Righetti, Finkenauer, & Finkel, 2013). Induction of an intuitive compared to reflective cognitive state resulted in increased donation to the common good (Lotz, 2015). Similarly, increased cognitive load resulted in more generous offers to others (Cornelissen, Dewitte, & Warlop, 2011; Schulz, Fischbacher, Thöni, & Utikal, 2014). Taken together, intuition compared to deliberation is related to increased prosocial behavior (Zaki, 2014). But are inter-individual differences in reflexive- and reflective-like processes discernable and of predictive value for later prosocial behavior?

The processing of and reaction to distress is a likely candidate predictor of helping behavior

(Habashi & Graziano, 2015). For example, Marsh, Kozak and Ambady (2007) found across a series of experiments that the ability to recognize facial expressions of fear, a clear signal of distress in another individual, predicted prosocial behavior. Here, we addressed the question if behavioral responses to an emergency situation are predictive of later helping behavior during Immersive Virtual Reality (IVR). While previous studies have used situations and measures of helping and other prosocial behaviors that are relevant to the individual, for example sharing in an economic game, they are low in terms of risk and danger to the participant and probability of being encountered in daily life. One way to circumvent this is to use the powerful tool of IVR. This technique allows researchers to explore situations that cannot be created in reality because they are either unethical or too dangerous for the participant. It further provides an increase in ecological validity while simultaneously maintaining experimental control, and measuring genuine phenomenological, behavioral and physiological outcomes (Blascovich et al., 2002; Gamberini, Chittaro, Spagnolli, & Carlesso, 2015; Rovira, Swapp, Spanlang, & Slater, 2009; Slater et al., 2006). This technique has successfully been used to study behavior in onlookers during a violent incident in which a victim is verbally and physically attacked by a perpetrator (Slater et al., 2013).

In the present study covert behavioral reactivity to an emergency situation in which a woman is in need of help, as measured by reaction times during low and high cognitive load, served as predictors of helping behavior. Following this behavior task, participants were confronted with a violent conflict between two individuals in a bar. The number of physical and verbal interventions made by the participant during this conflict served as helping behavior measures. We tested the hypothesis if reaction times to an emergency situation during high cognitive load, tapping into reflexive, intuitive processes, would predict later helping behavior during a violent conflict. It was not expected that behavioral measures when cognition is unrestricted would have predictive value.

As helping behavior is thought to be the result of one overarching mechanism (Preston, 2013; Zaki, 2014), we used two different situations to answer the question if an initial reaction to one situation (an emergency) is predictive of helping behavior in a different situation (a violent conflict). Given the foregoing, we additionally hypothesized that a tendency by the participant to describe the decision-making process during the violent conflict as intuitive, fast and reflexive would be positively related to the number of interventions. Lastly, given the close relationship between a disposition to experience feelings of sympathy for others, prosocial behavior (C. D. Batson et al., 1987; Carlo et al., 1991; Eisenberg & Miller, 1987; Eisenberg, Miller, et al., 1989b; Romer et al., 1986), and proxemics (Perry, Mankuta, & Shamay-Tsoory, 2015; Strayer & Roberts, 1997), (Gillath, McCall, Shaver, & Blascovich, 2008), we incorporate these measures as well.

Methods

Participants

Participants interested in football were recruited by advertisements around the Universitat de Barcelona campus and by means of word-of-mouth. Potential participants were to fill in an online questionnaire that asked about their interest in football and their favorite team and level of support for this team. Twenty-nine male supporters of F.C. Barcelona, between 18 and 29 years of age, were recruited. The median level of support for F.C. Barcelona on a scale from 1 (not at all) to 7 (very much so) was 5 with an interquartile range of 2. Participants had normal or corrected-to-normal vision and were screened for contra-indications for VR (e.g., epilepsy, recent alcohol intake). One additional participant was excluded before the start of the study because of voice problems. Participants received oral and written information prior to the study, but remained naïve to the goal of the experiment, and provided written informed consent. The compensation was ten Euros. The study was approved by the Comissió Bioètica of Universitat de Barcelona and carried out in accordance with the standards set by the Declaration of Helsinki.

Procedure

After explanation of the procedure by the experimenter, the participant provided informed consent and answered several questions on the intake of psycho-active drugs and alcohol, frequency of video game playing, level of knowledge in informatics and programming, and past experience with virtual reality. The study consisted of three parts; 1) cued reaction time task, 2) virtual reality scenario, and 3) questionnaires. The participants were not aware of any potential relation between the parts. After completion of the reaction time task, the VR procedure began and participants were told that they would enter a bar and meet some people inside with whom they were free to interact. Before entering the virtual environment, participants were fitted with the 3D glasses, head tracker, headphones, and a microphone. Participants entered the virtual bar and were asked to describe the environment in detail. Following this familiarization period, an adapted scenario from Slater and colleagues (2013) started. In the scenario the participant had a short free-flow conversation on F.C. Barcelona (e.g., results, favorite player) with a male virtual human (V, victim), a fellow Barça supporter who was wearing a Barça shirt. While the utterances of V have been prerecorded, the selection was done by an experimenter based on the response of the participants, allowing for a normal conversation to occur (mean±SD duration: 103±24s). During the conversation, another male virtual human (P, perpetrator), wearing a Real Madrid shirt, entered and sat at the bar. After a few minutes he stood up and walked towards V starting an argument about his shirt and his support of the club. During the argument V took a submissive, conciliatory role. Over time the verbal attack of P on V became increasingly intense and escalated into a physical attack of P on V. The conflict between P and V is the same for all participants (total time of conflict: 135s). **Figure 1** provides a visual representation of the scenario. Following the physical attack the program was terminated and participants exited the virtual environment. The session

was concluded with completion of several questionnaires. After debriefing the participant received his payment.

Cued reaction time task

An adapted cued reaction time task with cognitive load manipulation from Hortensius, Schutter & de Gelder (under review) was used. In between a response and a preparation cue, a 1s video clip depicting an emergency (falling woman) or non-emergency situation (woman standing up) was presented. Both go and no go cues (25% of the trials) were used and presented for 160ms. Participants responded as fast as possible to the go cue with the index finger of their dominant hand. During the reaction time task participants were instructed to simultaneously remember a phone number (see Spunt & Lieberman, 2013). This phone number could be easy (e.g, 888 - 888 -888, low cognitive load) or hard (e.g., 643 - 687 - 237, high cognitive load) to memorize. Before the onset of an eight trial reaction time block, a load instruction screen was presented for 3000ms. At the end of the block a memory probe was shown and participants indicated if the presented phone number was the same as the to be

Figure 1. Visual representation of the scenario. While the participants had a conversation with the victim (A), the perpetrator walks over to victim (B) and starts an argument (C - E) that becomes increasingly intense and eventually escalated into a physical attack (F). Please note that the viewpoint of these frames do not match the viewpoint of the participants as the actual scenario was in three-dimensional stereo vision and based upon the position of the participants in the CAVE.

remembered number (**Figure 2)**. The use of a cognitive load manipulation is well established method to impose restrictions on cognition and assess the role of intuition and automaticity (Cornelissen et al., 2011; Gilbert et al., 1988; Schulz et al., 2014; Spunt & Lieberman, 2013), importantly it does not rely on problematic reaction time reverse inference (Krajbich, Bartling, Hare, & Fehr, 2015). A pilot experiment (n = 5) revealed that manipulation of cognitive load was successful, $t(4) = 4.81$, $p < .001$, d = 2.15. Accuracy was higher in the low cognitive load condition, mean±SD percentage correct: 90±13.69 %, compared to the high cognitive load condition, 67.50±14.25 %.

Reaction times in the cued reaction time task serve as the main outcome measures and have previously been used to index action preparation or readiness (Hortensius, Schutter & de Gelder, under review). Faster reaction times are associated with increased action preparedness, while slower reaction times indicated decreased action preparedness, with respect to the presented situation. Adding the cognitive load manipulation would restrict cognitive involvement during the high load condition, while the low load manipulation would leave cognitive processes unrestricted.

After practice of the cued reaction time task (three trials, one no go trial), the cognitive load manipulation was added and participants completed a low and high cognitive load block with each containing three reaction time trials (one no go trials). For the practice trials video clips of a woman standing and waiting were used.

Virtual Reality System

The program was developed in the XVR programming platform (Tecchia, 2010), with the virtual characters animated with HALCA software (Gillies & Spanlang, 2010), and delivered by a 'CAVE' system (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). The CAVE consists of three back-projected walls and a front-projected floor, each measuring 3.69 by 2.25m, driven by a Master-node with four slave-nodes. Alternate images at 60Hz were presented to each eye of the participants synchronized with the projectors using RealD 3D CrystalEyes 4 glasses resulting in overall 3D stereo vision. A head tracker (InterSense IS900) was mounted on top of the glasses and fed the participants' head position and movement into XVR. Participants were fitted with headphones for auditory stimuli, and a microphone for voice recordings. The entire scenario was recorded using a video camera from the top of the CAVE filming the participant from the back to preserve anonymity.

Decision-making Questionnaire

To assess self-reported intuitiveness versus deliberativeness of the decision-making process during the conflict we included a questionnaire based on Rand and Epstein (2014). The questionnaire assessed the intuitiveness of the decision to verbally or physically intervene or not at two time points during the conflict as well as the overall decision to act (five items). After the participants were made familiar with the definition of intuitive and reasoned decisions

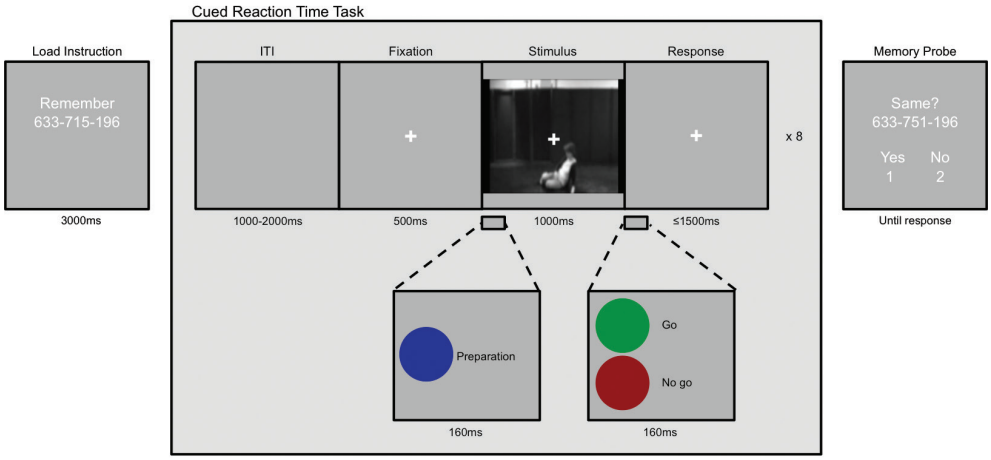


Figure 2. Cued reaction time task with cognitive load manipulation. Before each reaction time task block a low or high load instruction screen was presented. Participants were instructed to respond as fast as possible to the go cue with the index finger of their dominant hand while simultaneously remembering the phone number. Between a preparation and a response cue, a video clip depicting an emergency or nonemergency situation was shown. After eight reaction time trials a memory probe was shown and participants indicated if the shown phone number was the same as the to be remember one.

following Rand and Epstein (2014), they rated the statements on a scale from 1 (intuitive/fast) to 5 (reasoned/slow). The intervention scale of the decision-making questionnaire had a high reliability, Cronbach's α = .82. **Table 1** reports the items and responses. General intuitiveness was also assesses by non-intervention related aspects. These three items, assessing the intuitiveness of the interaction with V and internal reactions during the conflict, had a low reliability, Cronbach's α = .28, and were discarded from further analyses.

Trait Empathy Questionnaire

Trait levels of cognitive and affective components of empathy were measured with the Interpersonal Reactivity Index (M. H. Davis, 1980; 1983; Pérez-Albéniz, De Paúl, Etxeberría, Montes, & Torres, 2003).Perspective taking (the capacity to understand the thoughts and feelings of another individual) and fantasy (the ability to transpose oneself to a fictional situation*)* measure the cognitive component. The affective component is made up of the personal distress and empathic concern subscales. These two subscales differ in terms of focus of the emotional reaction. The former measures the experience of discomfort in the observer in response to distress in others (a self-oriented emotional reaction), while the latter measures sympathy and compassion in the observer for less fortunate others (an other-oriented emotional reaction). In line with the existing literature, we use the term sympathy when referring to the trait measure of an other-oriented emotional reaction. The four scales of the IRI all had high reliability in the current sample, Cronbach's α ≥ .72.

Table 1. Decision-making Questionnaire

Question	*Median (IQR)*
I tried to intervene, because my reaction was:	3 (3)
When the guy with the Real Madrid shirt started to insult the other guy, my verbal intervention was:	4 (3)
When he started to insult the other guy, my physical intervention was:	3 (3)
When the guy with the Real Madrid shirt started to push the other guy, my verbal intervention was:	4 (3)
When he started to push the other guy, my physical intervention was:	3 (2)
Overall decision-making	3.2 (1.8)

The scale ranged from 1 (intuitive/fast) to 5 (reasoned/slow). IQR = interquartile range. If the participants did not intervene, the question referred to the decision not to intervene.

Presence Questionnaire

Presence of the participant in the virtual word was assessed using a previous developed questionnaire (Pan, Gillies, & Slater, 2015; Sanchez-Vives & Slater, 2005; Slater & Steed, 2000). Presence is the notion that an individual feels and behaves as if he is in the virtual world despites knowledge of the virtual aspect. On a scale from 1 (low presence) to 7 (high presence) participants answered several questions that assess both the place illusion (the sensation of being in the virtual bar) and plausibility (the illusion that the conversation and conflict occurring in the bar were real). Both the place illusion and plausibility scales have good internal reliability in the present study, Cronbach's $\alpha = .85$ and $\alpha = .87$ respectively.

Data processing

Reaction time analysis

Reaction times below <150ms and >1500ms (responses after the offset of the response screen), as well as incorrect trials were removed from analysis (mean±SD percentage of trials removed: 1.86±1.55 %). We calculated the bias score for both the low and high cognitive load condition separately by subtracting the reaction times in the nonemergency from the emergency situation. Negative values indicate faster responses to the emergency situation. For the main analysis we corrected for the general task effects of the cognitive load manipulation by using the standardized residual of the bias scores after a linear regression with accuracy low − high cognitive load as predictor (Hortensius, Schutter & de Gelder, under review). Given the a priori predictions we used Spearman correlations to test if these bias scores during the cued reaction time task predicted intervention during the conflict.

Video coding

Helping behavior was defined as the number of verbal and physical interventions of the participant during the conflict in the virtual bar. Two people independently coded the videos. One of the experimenters and one independent person were instructed to count the number of verbal and physical interventions. The same definition of interventions was used as in Slater and colleagues (2011). Utterances directed at P or V were counted as verbal interventions. Laughing or sighs were not counted as interventions. Physical interventions

were defined as either an action together with a verbal intervention, or an action directed at P or V (e.g., stepping in-between P and V or a hand movement to signal P to stop). The number of counted interventions was highly correlated between the two coders; verbal interventions $r_s = .89$, $p < .001$, physical interventions, $r_s = .95$, $p < .001$. The coding of the videos was carefully compared between the two coders and a final review of all the videos was performed to provide solutions for discrepancies and to make sure that no intervention was missed. This revealed that the slightly lower correlation for the verbal interventions was because one of the coders did not count the whistles of a participant as verbal interventions. These whistles were used by the participant to get the attention of P and were at the end counted as verbal interventions.

Tracking

Throughout the VR scenario the head orientation and position of the participant as well as the position of V and P were tracked and recorded (X/Y/Z-coordinates). Please note that X is left/right, Y is up/down, and Z is forward/backward. The unit is meters and the center (0, 0, 0) of the CAVE lies on the front wall center floor. The signal was offline downsampled to 60Hz using Spline Interpolation (with a pre-downsample filter of 27Hz, 24dB/oct). When tracking was lost, the data during that time window was excluded ($n = 4$, ~2, 4, 9, and 16.5s). Besides mean and standard deviation displacement in terms of X- and Z-coordinates, the following outcome measures were calculated. Distance to V was calculated with the following formula:

$$\sqrt{(x_i - x_j)^2 + (z_i - z_j)^2}$$

Where x_i and z_i are the coordinates for V and x_j and z_j are the coordinates for the participant. The mean and standard deviation distance to V were calculated separately for the conversation and conflict period. The same approach, but limited to the conflict period, was used for the distance to P. Next, we calculated the time spend in proximity of V and P. Using the definition of social distances from proxemics (E. T. Hall, 1966), which are also found in virtual reality (Bailenson, Blascovich, Beall, & Loomis, 2003; Gillath et al., 2008; Llobera, Spanlang, Ruffini, & Slater, 2010), we calculated the time spend in public (between 3.7 m and 7.6m), social (between 1.2 m and 3.7 m), personal (between 0.46 and 1.2 m), and intimate (<0.46 m) distance. The well-known personal space bubble corresponds to an interpersonal distance of around 40 cm.

Results

Preliminary analyses

The cognitive load manipulation was successful, $t(28) = 7.62$, $p < .001$, d = 1.85. Accuracy

was higher in the low cognitive load condition, mean±SD percentage correct: 98.28±4.39 %, compared to the high cognitive load condition, 72.41±19.30 %. **Table 2** reports the reaction times and bias scores for the cued reaction time task. A main effect of cognitive load was observed, $F(1,28) = 9.59$, $p = .004$, $\eta_p^2 = 0.26$. Participants were faster in responding to emergency and nonemergency situations alike in the low cognitive load condition, mean±SD in ms: 318.08±41.12 ms, compared to the high cognitive load condition, 330.78±46.32 ms. No main effect for situation or interaction between situation and cognitive load was found, $F(1, 28) = 0.00$, $p = .98$ and $F(1, 28) = 0.26$, $p = .62$ respectively. Bias scores did not differ between the two cognitive load conditions, $t(28) = 0.51$, $p = .62$.

No suspicion of the procedure and no side effects to the virtual reality were reported. Median response (and interquartile range) for the place illusion questions was 4.24 (2.63) and for the plausibility 3.67 (2.17). **Table 3 and 4** report the rating for the individual items. These results are comparable to the ones obtained in previous studies (Pan et al., 2015; Slater & Steed, 2000).

The mean±SD number of interventions was 9.07±11.12, with 3.38±4.57 physical interventions, and 5.69±6.85. From the 29 participants, 9 refrained from any intervention. The first±SD intervention was 26.20±27.10s after onset of the conflict. As the number of verbal and physical interventions were significantly correlated, $r_s(29) = .83$, $p < .001$, we calculated one measure of helping behavior.

Figures 3 and **4** provide a visual representation of the movement and position of the participants with respect to V and P throughout the violent conflict. There was a significant shift in position of the participant during the conflict phase compared to the conversation phase, mean X- and Z-coordinates, $t(28) = 2.30$, $p = .03$, d = 0.42 and $t(28) = 4.38$, $p < .001$, d = 0.55 respectively. More variability in position was also observed, standard deviation of X- and Z-coordinates, $t(28) = 2.16$, $p = .04$, d = 0.49 and $t(28) = 4.90$, $p < .001$, d = 1.30 respectively. When V was attacked by P participants moved closer to V compared to the conversation phase, $t(28) = 2.24$, $p < .03$, d = 0.26, and the distance to V was more variable, $t(28) = 5.79$, $p < .001$, d = 1.58. Mean±SD distance to V and P during the conflict phase was 0.95±.20m and 0.74±0.14m respectively. Overall, participants were most of the time in personal distance to V and P (**Table 5**). Starting position, defined as the distance of the participants during the conversation to V, did not influence the number of interventions, $r_s(29) = -.01$, $p = .96$.

Main analyses

In contrast to the predictions, the bias score during the high cognitive load condition did not predict the number of interventions, $r_s(29) = -.23$, $p = .23$. Interestingly, the bias score during the low cognitive load condition predicted the number of interventions, $r_s(29) = -.36$, $p = .05$ (**Figure 5A**). Participants whom showed faster responses to the emergency compared to the

Table 2. Mean reaction times ± standard deviations for the cued reaction time task

	Low cognitive load	High cognitive load
Emergency	317.31±38.67	331.62±48.62
Nonemergency	318.86±44.11	329.93±44.75
Emergency – Nonemergency bias score	-1.55±25.70	1.69±22.53

Table 3. Place illusion Questionnaire

Question	*Median (IQR)*
Please rate your sense of being in the discussion in the bar, on the following scale from 1 to 7, were 7 represents your normal experience of being in a place	5 (3)
To what extent were there times during the experience when the discussion in the bar was the reality for you?	4 (2)
When you think back about your experience, do you think of the situation in the bar more as images that you saw, or more as somewhere you visited?	5 (3)
During the time of the experience, which was strongest on the whole, your sense of being in the bar, or of being in the real world of the laboratory?	5 (3)
Overall Place illusion	4.25 (2.63)

The scale ranged from 1 (low presence) to 7 (high presence). IQR = interquartile range.

Table 4. Plausibility Questionnaire

Question	*Median (IQR)*
How much did you behave during the discussion in the bar as if the situation were real?	4 (3)
How much was your emotional response during the discussion the same as if it had been a real situation?	3 (4)
How much were your thoughts you had during the discussion the same as if it had been a real situation?	4 (4)
To what extent were your physical responses the same as if it had been a real situation?	3 (2)
How much did you behave as if the guys were real?	3 (3)
How much was your emotional response to the two guys as if they were real?	5 (3)
How much were your thoughts in relation to the two guys as if they were real?	4 (4)
How much were you thinking things like "I know these guys are not real" but then surprisingly finding yourself behaving as if they were real?	4 (3)
How much did you have physical responses to the guys as if they were real?	3 (3)
Overall Plausibility	3.67 (2.17)

The scale ranged from 1 (low presence) to 7 (high presence). IQR = interquartile range.

Table 5. Mean ± standard deviations of the time spend in proximity of V and P.

	Public	Social	Personal	Intimate
V – Conversation	-	14.19 ±32.65	84.39±37.29	0.08±0.43
V – Conflict	-	17.37±32.13	114.47±33.58	1.55±6.86
P – Conflict	-	2.03±4.43	123.73±18.08	7.62±17.59

The definition for social distances from Hall (1966) was used. Time in seconds is reported.

nonemergency situation while cognition was unrestricted during the cued reaction time task intervened more during the conflict between P and V in the virtual environment. To further quantify this effect we contrasted the intervention with the no intervention group. Results showed a between groups difference in bias scores in the low cognitive load condition, Mann-Whitney *U* test: $U = 48$, $p = .05$, $r = -.37$, but not in the high cognitive load condition, $U = 82$, $p = .73$. Under condition of limited cognitive restriction, participants that would intervene had a negative bias score during the reaction time task, thus reacted faster to the emergency. The participant that did not intervene showed slower responses to the emergency situation (**Figure 5A**).

Is helping behavior related to a more intuitive decision-making process? In line with our hypotheses, we found that a tendency to rate the decision to intervene during the conflict as more reflexive was related to more interventions, $r_s(29) = -.38$, $p = .04$ (**Figure 5B**). Directly contrasting the intervention with the no intervention group, showed a near significant difference in self-reported decision-making, $U = 50.5$, $p = .06$, $r = -.35$. The participants that intervened reported a more intuitive decision to intervene, while the participants that refrained from intervention reported a more deliberate decision-making process (**Figure 5B**). The self-reported decision-making style was not correlated with the bias scores during the cued reaction time task, $p \geq .37$.

Exploratory analyses

It is likely that a mediating factor plays a role in these contrasting results. Sympathy has consistently been linked to costly helping (C. D. Batson et al., 1987; Carlo et al., 1991; Eisenberg & Miller, 1987; Eisenberg, Miller, et al., 1989b; Romer et al., 1986), and recently we showed that trait levels of sympathy predicted faster responding to an emergency in a cued reaction time task similar to the one used here but without cognitive load manipulation (Hortensius, Schutter & de Gelder, under review). Therefore, we investigated the role of a disposition to experience sympathy in an exploratory analysis. In contrast to previous observations, sympathy was not directly related to bias scores, $r_s(29) = -.19$, $p = .34$, nor to the number of interventions, $r_s(29) = .13$, $p = .51$. However, sympathy was negatively related to decision-making, $r_s(29) = -.38$, $p = .04$, and was higher in intervening compared to non-intervening participants, $U = 45.5$, $p = .04$, $r = -.39$. In other words, a disposition to experience sympathy for others is related to a tendency to report the decision to help during a violent conflict as a consequence of an intuitive and fast process. Is trait sympathy also related more objective measures of prosociality? As the distance of the participant to a person in distress has served as a proxy for prosocial behavior (Perry et al., 2015; Strayer & Roberts, 1997), and is correlated with feelings of compassion (Gillath et al., 2008), we investigated if trait levels of sympathy predicted distance to V and P. Results showed that sympathy was significantly related to reduced distance to P, $r_s(29) = -.44$, $p = .02$, but not to V, $r_s(29) = -.18$, $p = .34$. Participants with a disposition to experience feelings of concern for others moved closer to P during the violent conflict (**Figure 6**). The latter effect is not surprising given the

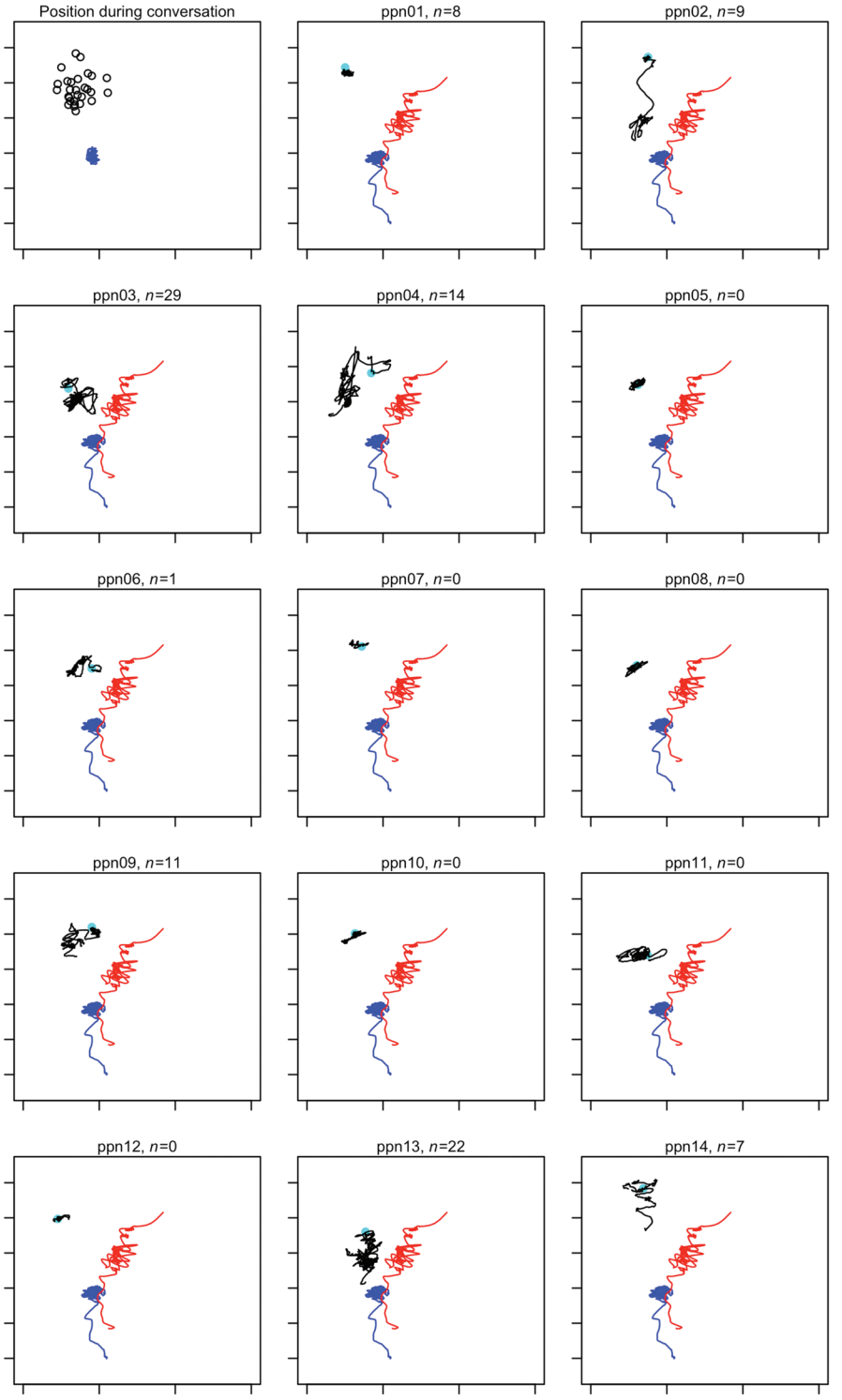


Figure 3. Movement of the participant and V and P during the violent conflict. *n* indicates number of interventions.

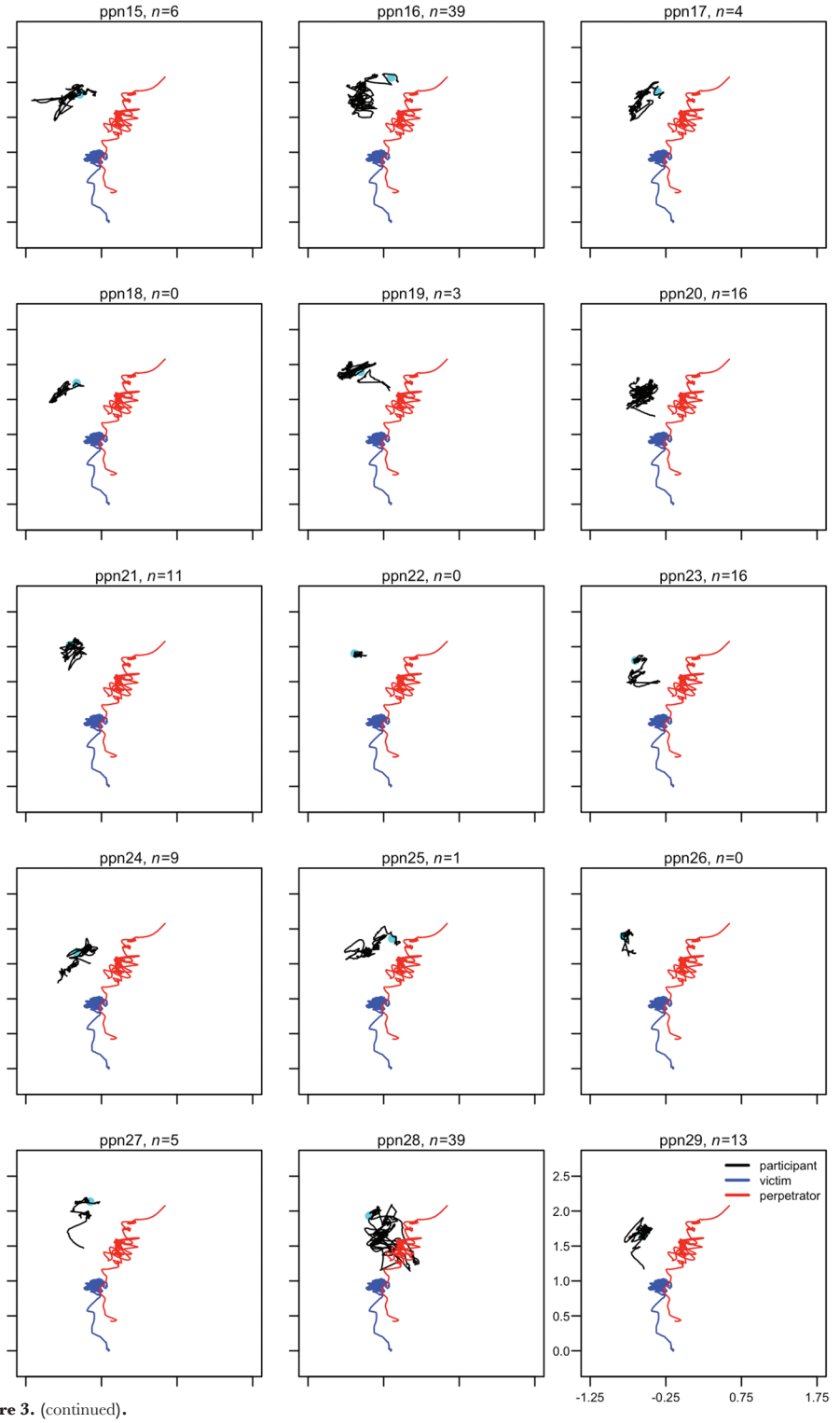


Figure 3. (continued).

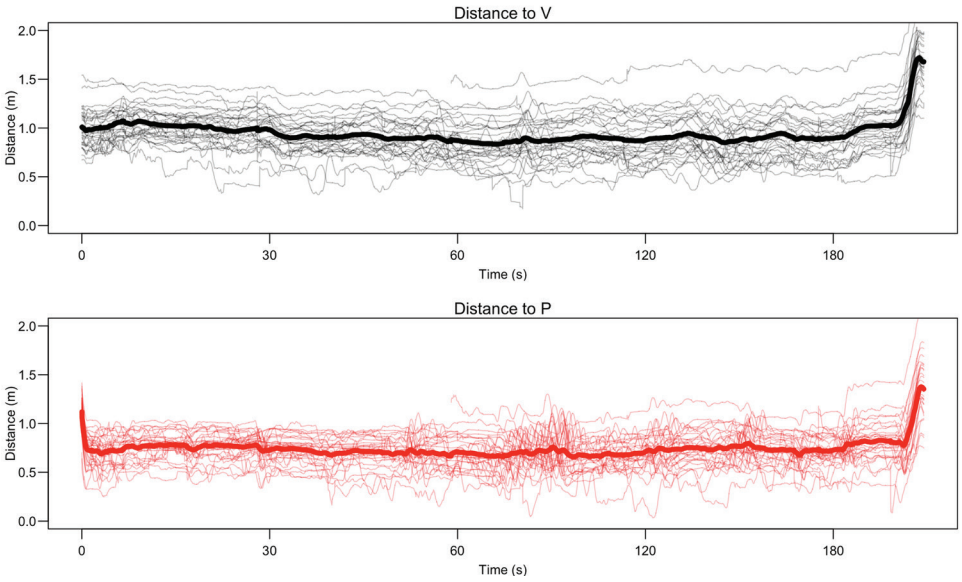


Figure 4. Distance to V and P during the violent conflict. The rapid increase in distance to P and V at the end is because of the physical fight. Thick lines indicate the mean distance across participants. Please note that if lines are discontinued tracking was lost (n = 4).

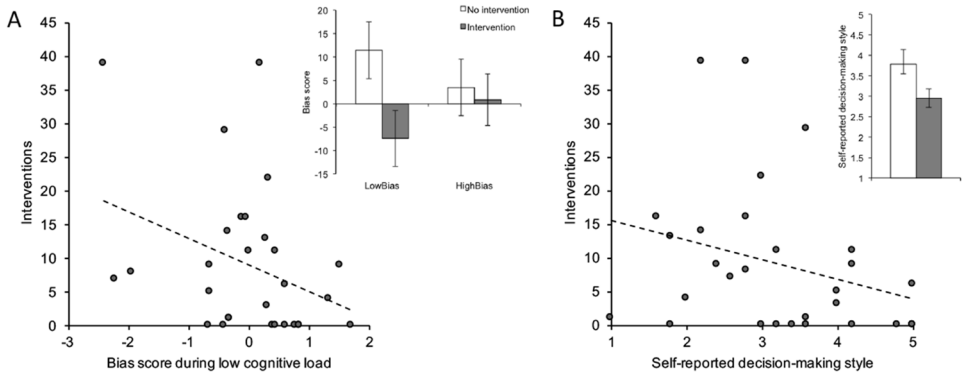


Figure 5. Prediction of the number of interventions by behavioral reactivity to an emergency and self-reported decision-making style. Participants that responded faster to the emergency compared to the nonemergency situation during the cued reaction time task with low cognitive load intervened more during the violent conflict (A). A tendency to rate the decision to intervene as more intuitive and reflexive was related to more intervention (B). Inset shows between group differences for behavioral reactivity during low cognitive load (A) and self-reported decision-making style during the violent conflict (B). Participants that intervened showed faster responses to an emergency situation during low cognitive load and reported the decision to act as intuitive and fast.

nature of the scenario and the possible outcome of prosocial intervention. Getting closer to the aggressor to prevent a physical attack and possible harm to the victim is an efficient strategy and could serve as helping by proxy.

Discussion

The goal of the present study was to predict helping behavior during a violent conflict from behavioral reactivity to an observed emergency. Reaction times during the low, but not high, cognitive load condition predicted interventions during the violent conflict. While small in terms of effect size, results show the feasibility to use reactions in one emergency context to predict helping behavior in a different context. In addition, participants that tend to report their decision to intervene as intuitive and reflexive provided more help. Lastly, exploratory analyses revealed that sympathy was related to this self-reported intuitive decision-making style and to a decreased distance to the aggressor.

In contrast to the prosociality-intuition link (Rand & Nowak, 2013), we did not find support for the prediction of helping behavior by behavioral measures under conditions of restricted cognition. While we cannot definitely assess the direct effect of cognitive load on emotional and cognitive processing of an emergency situation, cognitive load manipulations have reliably been used to restrict the influence of cognition and top down control (Gilbert et al., 1988; Rameson et al., 2012; Spunt & Lieberman, 2013), and to bias the participant towards a more intuitive style (Cornelissen et al., 2011; Schulz et al., 2014). One, albeit speculative, explanation might be the overshoot of the cognitive load manipulation. Even under conditions of low cognitive load the emergency situation is processed implicitly given the nature of the cued reaction time task. Participants are focused on the go and no go cue, fixate on the center of the screen, and are not made aware of the special nature of the video clips shown during

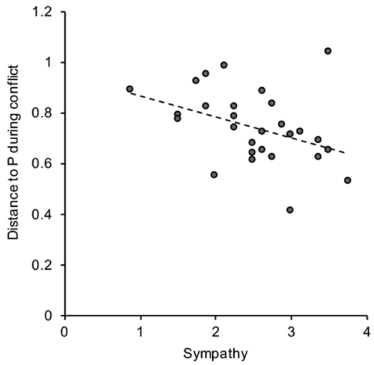


Figure 6. A disposition to experience other-oriented feelings during situations of distress was related to a decreased distance to P during the violent conflict.

the task. Related, the high cognitive load condition might result in restriction of perceptual processes and lead to a form of attentional unawareness of the actual stimuli, that is the emergency situation.

Another more likely explanation is the notion that prosocial behavior is not solely linked to, or predicted by, intuitive, automatic and reflexive processes. Several studies suggest that the perception of distress in another individual serves as a function of attentional processes (Gu & Han, 2007; Rameson et al., 2012). In an intriguing study, Cowell and Decety (2015) investigated the interplay between event-related potentials linked to automaticity and top-down control and prosocial behavior in children between three and five years of age. First, children passively observed scenes that showed either pro- or antisocial behavior of cartoon figures while simultaneously recording ERPs. Following this, children were given the opportunity to share their reward with another, anonymous, child. Results showed that while both early and late ERPs show distinguishable patterns to the observation of pro- and antisocial acts, only the late waveform, related to controlled processes, predicted sharing behavior.

There is a growing body of evidence on how empathic responses, ranging from a cognitive understanding to an affective reaction, are modulated by situational and dispositional factors, but a crucial aspect is the behavior to provide help when confronted with an individual in need (C. D. Batson, 2009). A wide variety of studies have provided important insight into the person-by-situation interaction (for example Batson:1987wa Eisenberg & Miller, 1987; Romer et al., 1986), neural mechanisms (FeldmanHall, Dalgleish, Evans, & Mobbs, 2015; Marsh et al., 2014), and neurocomputational processes (for example Hutcherson, Bushong, & Rangel, 2015), that contribute to the occurrence of helping behavior and functional altruism. However, this behavior is complex with several proximate causes. This explains why so far no one single trait or a combined set of traits or predictors have been found. It is likely, as also suggested by the present result, that helping behavior is the result of a complex interplay between intuitive, reflexive and deliberate, reflective mechanisms.

In an important review, Graziano and Habashi (2015)suggest that there are not necessary distinguishable prosocial traits. Researchers should instead 'think of dispositions as parts of processes and systems', where 'prosocial dispositions are summary terms for observed processes' (p. 250). They suggest that the prosocial and ultimately altruistic personality are built up from thoughts (e.g., intent, beliefs), feelings (e.g., empathy), and behavior that are highly linked and correlated and are the result of a motivational system. The dual-process, sequential opponent motivational system (W. G. Graziano & Habashi, 2010; W. G. Graziano & Tobin, 2009) nicely fits recent theoretical accounts on empathy (Zaki, 2014) and altruism (Preston, 2013) and provides the foundation for a wide variety of prosocial behaviors. As the name suggests two opposing evolutionary conserved motivational systems are sequentially activated when one is confronted with an emergency or other distressful event, the fight-

freeze-flight and parental care system. Helping behavior is the complex interplay of these two systems that differ in terms of automaticity. The fixed action patterns of the first system are related to distress (process A) and a freezing response, and consequently inhibits helping behavior. The slower system of parental care counteracts these processes (process B) and is sympathy-driven and facilitates the occurrence of helping behavior and other forms of prosocial behavior. This later system explains the present and previous results (Hortensius, Schutter & de Gelder, under review). In line with the strong link between sympathy and prosocial behavior (M. H. Davis, 2015), we observed that sympathy was related to reduced distance to the perpetrator, self-reported intuitive decision-making style (present study), and faster responding to an emergency (Hortensius, Schutter & de Gelder, under review). Thus, prosocial thoughts, feelings and behavior are the result of one overarching sympathy-driven system (for example Penner, Fritzsche, Craiger, & Freifeld, 1995) that can differ in terms of automaticity. For example, a belief system of the individual in which helping behavior is seen as automatic, reflexive, internal might be beneficial to actual occurrence of helping behavior (Bierhoff, Klein, & Kramp, 1991; Rand et al., 2014; Rand & Epstein, 2014).

In conclusion, we have used a multilevel approach and incorporated behavioral reactivity, self-reported decision-making, and proxemics during Immersive Virtual Reality to study helping behavior during a violent conflict. Results showed that faster responses to an emergency situation while cognition is not restricted are predictive of later helping behavior and suggest an important role for a disposition to experience other-oriented responses to distress in the occurrence of helping behavior.

Chapter 8

General discussion

Introduction

The goal of this thesis was to provide insights into the neural mechanisms of the reactive aspects of social interaction. How is the human brain equipped to deal with the wide range of social emotional situations that occur in daily life? From helping an older woman that fell on the ground, to confrontation with an aggressive individual that harasses an innocent man. This thesis was divided into two parts. Part I dealt with the perception of and reaction to threat signals, while part II studied the prosocial consequences of the perception of distress. A multidimensional framework was used with transcranial magnetic stimulation (TMS), functional magnetic resonance imaging (fMRI) in the healthy and damaged brain, and eye-tracking complementing behavioral testing. In an exciting new endeavor, immersive virtual reality was used to study helping behavior in a naturalistic setting. In this chapter, the results of the empirical work (**Table 1**) and their theoretical implications will be discussed and integrated. This will be done for part I and II separately. In a last section several new and important directions for future research derived from this thesis will be described.

Part I – Summary and discussion

We are confronted with threat almost at a daily basis. Fortunately, we are well equipped to deal with such situations. The first part of this thesis, **chapter 2 – 4**, focused on the neural architecture that allows humans to cope with threat. A working model based on the dual route perspective of affective perception as outlined in de Gelder, Hortensius and Tamietto (2012)

Table 1. A one-sentence summary of the main findings of this thesis

Chapter	Main finding
Part I	**The Devil – Threat**
2	Increase in motor corticospinal excitability regardless of direction of anger, while an emotion by direction interaction underlies explicit recognition
3	Reflexive gaze behavior to angry bodily but not facial expressions in high dominant people and this is likely to be mediated by detection but not recognition of the signal
4	A disruption in a prefrontal midline – temporal pole – inferior parietal lobule network during threat processing after damage to the basolateral amygdala
Part II	**Sympathy – Distress**
5	A decrease in activity in the pre- and postcentral gyrus and medial prefrontal cortex with an increase in bystanders during an emergency
6	Personal distress predicts the negative effect of bystanders on responding to an emergency
7	Behavioral reactivity to an emergency when cognition is not restricted predicts later helping behavior during a violent conflict

served as a starting point. Together, the results obtained in the first part concur with the notion of two separate but interrelated pathways for detection and recognition, which underlie important changes at the level of physiology, perception, behavior, and phenomenology. The results from **chapter 2** and **3** highlight the importance of fast and reflexive reactions to threat that are mediated by the detection route, while **chapter 4** shows that damage to one specific region leads to a cascade of changes across the detection and recognition routes (**Figure 1**).

Defensive distance and threat

When confronted with threat several distinct reactions occur in the individual that mediate the fight, flight or freeze response. These reactions range from effects on attention (Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2010; 2011; Schmidt, Belopolsky, & Theeuwes, 2015a; 2015b; Vuilleumier, 2005), startle response (Lang et al., 1990), heart rate (F. K. Graham & Clifton, 1966; Hagenaars et al., 2014), fast facial reactions (Dimberg & Thunberg, 1998; Grèzes, Philip, Chadwick, Dezecache, Soussignan, et al., 2013b), motor corticospinal excitability (Borgomaneri et al., 2015b; Schutter et al., 2008b), and muscles activity (Huis In 't Veld, van Boxtel, & de Gelder, 2014a; 2014b). As described in **chapter 1** the defensive system is the combined result of approach or avoidance motivation and defensive distance. The latter aspect is largely overlooked in the literature on human threat processing. One intriguing and timely study is that by Åhs and colleagues (2015). In a series of four experiments that incorporated immersive virtual reality (IVR) and basic psychophysiology, the authors showed that interpersonal distance influenced defensive avoidance. That is, interpersonal distance increased startle amplitude and fear memories, and distance to a

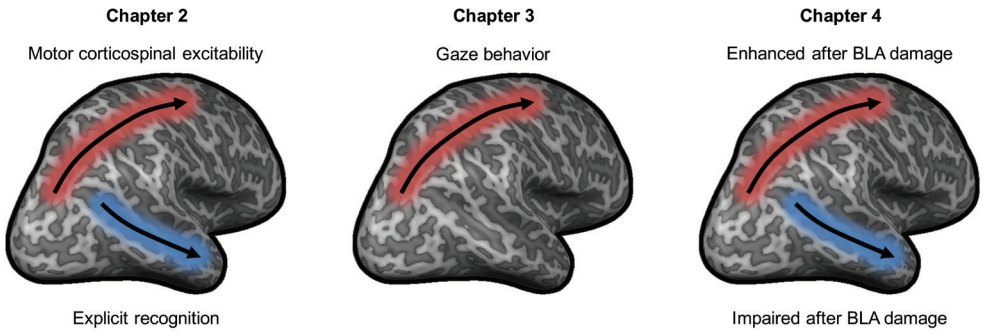


Figure 1. The results of the first part of the thesis in a simplified graphical representation of the two parallel routes as described in the working model. The arrow in the dorsal stream reflects the detection route, while the arrow in the ventral stream denotes the recognition route. The detection route underlies the increase in motor corticospinal excitability for anger regardless of direction (**chapter 2**), the reflexive gaze behavior to angry bodily expressions in high dominant people (**chapter 3**), while activity in this stream is enhanced during the processing of threat after BLA damage (**chapter 4**). The recognition route underlies the emotion by direction interaction found in the recognition task (**chapter 2**), and processing in this route is impaired after BLA damage (**chapter 4**). Please note, this is a very simplified representation as the routes are not exclusive and major parts of the routes are not visible (e.g., superior colliculus, amygdala). An inflated cortex representation of the author is used.

virtual human that served as a previous fear cue was increased and transferable to a new environment. Going beyond defensive avoidance, the authors observed decreased startle amplitude to proximal cues that served as rewards, indicative of defensive approach.

In keeping with the importance of defensive distance, **chapter 2** reported on a single-pulse TMS study that investigated defensive reactions in the observer to threat with variable direction. The movement of the threatening person was either towards or away from the observer resulting in proximal or distal threat. Single-pulse TMS was used to measure motor evoked potentials in response to brief presentations of angry, fearful or neutral individuals that jumped towards or away the observer. In addition, participants completed a three-alternative forced-choice emotion recognition task. The results showed differential effects of threat direction on the level of physiology and explicit recognition. An incongruence effect was observed for explicit recognition of anger and fear. That is, anger was better recognized when directed towards the observer compared with when directed away, while the opposite pattern was found for fear. In contrast to explicit recognition, motor corticospinal excitability did not serve as a function of direction. In the face of anger, motor corticospinal excitability levels increased independent of direction compared to fear and neutral signals.

These results nicely dovetail with the dual route perspective. First, automatic reactions to threat, at least as measured with motor corticospinal excitability, are not influenced by direction. A rapid detection route mediates this direction-independent processing of threat. This would allow for fast perception-action coupling thereby increasing behavioral flexibility in the face of threat. In this study anger regardless of direction was likely the signal with the highest threat value for the observer. Within the second route the emotional content together with the direction, and thus relevance to the individual, is extracted. This framework is in line with other observations. A recent study found that relevance of bodily threat modulates activation in a frontal-based route, but not in an emotion-action route that includes regions such as the amygdala and premotor area (Grèzes, Adenis, Pouga, & Armony, 2013a). A different line of research suggest that contextual effect on facial (Sinke et al., 2012; Van den Stock, Vandenbulcke, Sinke, Goebel, & de Gelder, 2014b) and bodily expression perception (Van den Stock et al., 2014a) are present in ventral regions such as the extrastriate body area and parahippocampal place area, but not in regions implicated in the detection route. An outstanding question is how top-down processes, or the recognition route, modulate this initial, possibly aberrant detection of and reaction to threat signals.

Functional significance of bodily threat

One important aspect of reaction to threat is the reflex-like nature of the reaction and the personality of the individual. Even under conditions of attentional and sensory unawareness (Tamietto & de Gelder, 2010), threatening signals result in distinct consequences. A recent meta-analyses found evidence for an attentional bias towards threat in anxious individuals even in the absence of visual awareness of the signal (Bar-Haim, Lamy, Pergamin, Bakermans-

Kranenburg, & van IJzendoorn, 2007). Given the importance of emotional signals in building and maintaining social hierarchies, one would expect that this is also the case for behavioral patterns of dominance and submission. This is indeed observed (Terburg & van Honk, 2013; van Honk & Schutter, 2007).

Extending the literature, the results of **chapter 3** showed that inter-individual differences in dominance predicted gaze-aversion to non-conscious presented bodily expressions of anger. Dominance traits were positively related to slower gaze-aversion from angry compared to happy bodily and face and body compound expressions. Interestingly, this was not found for gaze-aversion from facial expressions in isolation. A follow-up study showed that the possible mechanism for this contrast between faces and bodies lies in the detection of the category, but not in the recognition of the emotional content. That is, the observer is aware of the body but not the emotional value of the body.

These findings not only confirm the dual route of affective perception, but also emphasize the functional significance of bodily expressions of threat. Emotional signals have so far only been discussed as one largely coherent signal in this thesis. However, the smaller building blocks of social interaction are made up of verbal and non-verbal cues, for example facial, vocal, and bodily expressions. The field of social affective neuroscience was until recently largely "face-centric". This is well illustrated by the literature on neuroimaging of emotion perception. The first neuroimaging study on emotional face perception was already published in 1993 (George et al., 1993), shortly followed by sounds (George et al., 1996), and pictures (Lane et al., 1997). Only in 2003 the first study on emotional body expression perception was published (Hadjikhani & de Gelder, 2003). While largely ignored in the beginning days of social affective neuroscience, bodily expressions have now widely been used to study neural processes underlying social interaction (de Gelder et al., 2010; de Gelder & Hortensius, 2014; Grèzes & Dezecache, 2014; Grosbras & Paus, 2006). Importantly, several naturalistic observations and neuroscientific findings point to the functional dominance of the body over the face in signaling threat.

Think of how animals establish dominance, or how animals fight, and the significance of the body will immediately become clear. Bodily expressions are primary emotional signals, complemented by facial and vocal expressions. This is also well appreciated in humans. An aggressive person with arms sweeping around the body, fists clenched, and shoulders up high, is a looming stimulus that warrants fast reactions. Bodily expressions have a high biological relevance, ecological validity, and tight action-coupling (de Gelder, 2009). If an evolutionary conserved mechanism underlies the detection and perception of emotional expressions, this would be certainly not be biased towards the processing of facial expressions.

Directly contrasting neural activation during conscious perception of face and body expressions of emotion showed that bodily compared to facial expressions resulted in more

activation in regions such as the extrastriate body area and temporoparietal junction but also inferior parietal lobule and superior temporal sulcus (STS) (Kret et al., 2011).These last two areas have been implicated in the detection of threatening bodily expressions. Stimulation of the IPL resulted in increased detection of changes in fearful bodily expressions (Engelen et al., 2015). Likewise, not only did stimulation of the STS results in a selective increase in the detection of changes in threatening body postures (Candidi, Stienen, Aglioti, & de Gelder, 2011), disrpution of this area increases the awareness of a fearful body, but not fearful face (Candidi, Stienen, Aglioti, & de Gelder, 2015). However, the results of **chapter 3** showed differences between faces and bodies under conditions of non-conscious perception. This poses the question if bodies are more efficiently processed.

In a recent study, we used breaking continuous flash suppression (CFS-b) to shed more light on this issue (Zhan, Hortensius, & de Gelder, 2015). With CFS-b the suppression time of a stimulus can be measured and this provides important clues on non-conscious processing (T. Stein, Hebart, & Sterzer, 2011). For example, CFS-b results showed that faces and bodies are preferentially processed (T. Stein, Sterzer, & Peelen, 2012). In this recent study we measured the differences in suppression time between neutral, fearful, and angry facial and bodily expressions (Zhan et al., 2015). Crucially, opposite suppression times for angry facial and bodily expressions were observed. While angry faces were suppressed for a longer duration compared to neutral and fearful faces, angry bodies broke suppression faster compared to fearful and neutral bodies. As the duration outside of awareness is the combined sum of the content of the stimulus (e.g., face or body, and emotion) and low-level visual effects (e.g., contrast, luminance), we controlled for low-level visual effects. While the suppression time was indeed influenced by some lower-level visual properties of the stimuli, this explained the results only to a very small extent and did not change the results. The dominant factor that modulated suppression time was still the emotional content of the stimulus.

Detection and recognition of social threat

Together these findings suggest that threat is better communicated by bodily compared to facial expression. Indeed, while some studies found a detection advantage for angry facial expression (for example E. Fox et al., 2000), a recent meta-analysis found no detection or recognition advantage for angry facial expressions (Nummenmaa & Calvo, 2015). While facial and bodily expressions are the most commonly perceived social emotional signals, they are hardly ever perceived in isolation. The emotion signal is most often a blend of facial and bodily expressions. Proper integration is crucial for defensive reactions.

The aim of the last chapter of the first part, **chapter 4**, was to investigate the effect of basolateral amygdala (BLA) damage on the processing of face body compounds. The BLA is a crucial region in the processing of threat. Five participants with Urbach-Wiethe disease (UWDs) who have focal BLA damage and twelve matched controls viewed congruent and incongruent face-body compounds. Results showed that BLA damage leads to differential

activity in a prefrontal midline (PFC) – temporal pole (TP) – inferior parietal lobule (IPL) network. First, UWDs compared to controls showed more activation for fearful versus happy bodies in the right IPL, but less in the left fusiform gyrus. Crucially, the latter region showed increased functional connectivity with the left IPL in the UWDs compared to controls. While under the same task conditions, the right IPL showed increased coupling with the right subgenual anterior cingulate cortex in UWDs compared to controls. Second, when facial and bodily expressions were shown simultaneously as part of a compound stimulus but differ in valence, decreased activation in the bilateral TP, but increased activity in the prefrontal midline, that is the right medial orbitofrontal, ventromedial prefrontal, and dorsal medial prefrontal cortex was observed in UWDs compared to controls. Results from the functional connectivity analyses were inline with this division between the prefrontal- and temporal network.

These results provide new information on aberrant functional integration of, and reaction to, social stimuli after BLA damage that could potentially lead to hypersensitivity for threat. As the functional roles of the individual nodes in this PFC-TP-IPL network have been extensively described in **chapter 4**, the importance of integration of multiple emotional signals and the dual route will shortly be commented on. Perception is not straightforward. How we perceive and thus react to the world is influenced by host of factors. Perception is in essence biased. When confronted with threatening situations recognition follows detection. Rapid crude processing is followed by a more careful analysis of the situation. As the two routes run in parallel and are connected, a variety of changes with varying results can occur. For example, early emotion processing either mediated by the subcortical or cortical pathway can bias upstream processing in the recognition route. A brief view of a defensive posture with a smile can bias the processing towards the former. The initial labeling of a non-threatening signal as threatening at an early stage could potentially result in not only reflexive reactions, but also conscious recognition of the situation as threatening. The possible reflexive reaction that is normally counteracted in the case of a false alarm by inhibitory processes might take place in the absence of such control mechanism. In sum, there are multiple ways in which initial or late atypical processing of emotional signals result in perceptual and possible behavioral deficits, and the proper integration of emotional signals is crucial.

For example, Kret and de Gelder (Kret & de Gelder, 2013) showed across a series of four experiments that not only are male violent offenders more distracted by angry males and confuse a fearful male for an angry male, they have a deficit in combining different emotional signals. When a happy face is paired with an angry body, the percept in the violent offenders is biased towards the bodily expression. Similarly, the presentation of a person with a neutral expression in a threatening context increased activation in the extrastriate body area (Sinke et al., 2012), in line with a perceptual bias effect (de Gelder & Bertelson, 2003). Conscious interpretation can also bias processing of social situations, as is the case in the hostile attribution bias (Crick & Dodge, 1994). Dodge (1980) found that aggressive

boys, when confronted with an ambiguous social situation involving another individual were more likely to judge the intent of the other person as hostile instead of benign. In total, an adequate defensive system in response to threat depends on a delicate interplay between a rapid detection-reaction system and slower recognition abilities.

Part II – Summary and discussion

While threat and other negative aspects of social interaction play an important role in everyday life, so do empathy and prosocial behavior. In the second and last part of this thesis, **chapter 5 – 6**, the influence of contextual and dispositional factors on the perception of and reaction to distress and the occurrence of helping behavior was investigated. Together, the results of the second part provide an important new perspective on the bystander effect and helping behavior and fit the Dual-Process Sequential Opponent Motivational System. The results of **chapter 5** and **6** provide an explanation for the bystander effect that goes beyond higher-order cognitive mechanisms and explanations and provide evidence for a negative effect of bystanders already at the level of action preparatory processes. The results of **chapter 7** show that behavioral reactivity under low cognitive load to an emergency predicts later helping behavior during a violent conflict.

Beyond cognitive explanations for the bystander effect

In the late sixties, Latané and Darley (1970) initiated an extensive research program on the effect of bystanders on helping behavior during an emergency. Since their seminal first paper on the bystander effect (Darley & Latané, 1968), this reduction in helping behavior in the presence of others has been widely observed (Latané & Nida, 1981). A recent meta-analysis comprising data of 7,700 participants from 53 articles showed an effect size of -0.35 (Fischer et al., 2011). While many studies have been performed since, the explanations have not evolved much after the first description by Latané and Darley (1970). The three psychological processes that affect the decision to act, diffusion of responsibility, evaluation apprehension and pluralistic ignorance, are still the dominant explanations for the bystander effect. However, several aspects are unknown or unexplained. While a situational and cognitive approach is crucial, it forgets the more automatic, implicit, reflex-like processes that are likely to occur when one is confronted with another individual in need of help, and ignores a large body of work from contemporary research on empathy, helping and other prosocial behavior (Preston, 2013; Rand & Nowak, 2013; Zaki, 2014), as well as emotion (Frijda, 1986). What if the bystander effect is studied from a different angle, using a bottom-up approach that takes into account naturalistic observation and experimental findings from social affective neuroscience that stresses the reactivity aspect of social interaction? As has been showed and discussed throughout this thesis the notion that the observation of a threatening signal is directly coupled with action is well appreciated. There are no substantial arguments to

suggest that this is not the case for emergency situations. Contemplating a situation is unlikely to be the most adaptive response. To act upon the situation by preparation of action plans will give the organism a temporal advantage and increases behavioral flexibility by selecting the most adaptive response. It seems unlikely that only a conscious decision precedes helping behavior. This then, should also be reflected in the neural consequences when observing an emergency in the presence of bystanders.

The aim of **chapter 5** was to investigate the neural basis of the bystander effect. To tap into implicit processing participants performed a color-naming task. In this task three colored dots are shown and participants indicated whether these dots had the same or whether they had different colors. Crucially, the dots are presented during a movie of an emergency with varying number of bystanders (none, one, two and four). Confirming our hypothesis, the results showed a decrease in activity with the increase in group size in the left pre- and postcentral gyri and left medial prefrontal cortex. The increase in bystanders resulted in a parametric increase in activation in vision- and attention-related regions, including the right superior occipital and lingual gyrus.

These findings suggest that an increase in bystanders during an emergency coincides with a decrease in activity in brain regions important for preparation for action and situation-response coupling. In view of tranditional explanations of the bystander effect one would expect to find the involvement of the so-called metalizing and/or empathy network (Kennedy & Adolphs, 2012). While these networks are often found to be activated in the face of distress (Lamm et al., 2011), no bystander-related increase or decrease in activity was found. This is not surprising given that the majority of published studies focused on deliberate observation of an individual's suffering using stimuli that are quite distant from situations one would encounter in daily life (for example a needle penetrating a hand). **Chapter 5** focused on the neural consequence of an unintentional and implicit observation of an emergency with bystanders, a situation that, unfortunately, appeals to everyday life. Likewise, everyday life is not an emotion recognition task. The study of implicit observations of social situations is a interesting and valuable new approach to understand the neural mechanisms that drive possible behavioral reactions of an individual (de Gelder & Hortensius, 2014), and is necessary for going beyond emotional labeling and cognitive processes. For example, observing a situation in which an individual threatens another individual increased activation in the premotor area and putamen independent of attentional demands (Sinke et al., 2010). In a recent fMRI study, we showed the influence of personality factors and the focus of attention during a violent conflict (aggressor or victim) in a network encompassing categorical and emotion areas (Van den Stock, Hortensius, Sinke, Goebel, & de Gelder, 2015a).

As discussed in the general introduction (**chapter 1**) and throughout this thesis preparation for action plays an important role in social interaction. The results of the fMRI study in **chapter 5** revealed that bystanders already influence this process. Related, the decrease in

activation in the MPFC might suggest a decoupling between the situation and response. A study by Rameson and colleagues (2012) showed the importance of this region in helping behavior. Activity in the MPFC was positively correlated with daily helping behavior and activity in the same region was enhanced in participants with higher trait levels of empathy when implicitly confronted with distressed individuals. While the fMRI results already pointed towards a negative effect of bystanders on action processes, several questions remain. How do dispositional factors influence this effect, and can we use more sensitive measures that go beyond reverse inference?

Personal distress and the bystander effect

The effects of personality traits on helping behavior have been largely ignored in studies of the bystander effect. As an illustration consider the following. The only hit for the keyword 'personality' in the recent meta-analysis that encompassed ~40 years of research (Fischer et al., 2011) was with journal names in the reference list (for example 'Journal of Personality and Social Psychology'). The general thought is that situational factors on helping behavior dominate possible personality influences. Despite this wide held belief, some researchers have studied the contribution of dispositional factors in social norm following (Darley & Latané, 1968), masculinity (Tice & Baumeister, 1985), and embarrassment (Zoccola, Green, Karoutsos, Katona, & Sabini, 2011). So far, no personality traits have been identified that are consistently related to bystander effect. However, in other fields of psychology the effects of inter-individual differences on helping behavior have been widely appreciated. The work led by Batson and Eisenberg in the 1980s showed the importance of sympathy and personal distress in helping behavior (for example C. D. Batson et al., 1987; Eisenberg & Miller, 1987). To date, no direct testing of the influence of these factors on the reaction to distress when bystanders are present has been performed.

To fill this gap, the research described in **chapter 6** investigated the interplay between a disposition to experience sympathy and personal distress and the bystander effect in four experiments. It was hypothesized that only personal distress would predict the negative effect of bystanders on responding to an emergency. Indeed, in the first experiment without bystanders, both sympathy and personal distress were related to faster responses to an emergency. However, experiment 2 showed that perspective taking and not personal distress predicted the slowing in reaction times with an increasing number of bystanders during an emergency. In a follow-up experiment, single-pulse TMS was used to get a direct readout of the motor system during the reaction to an emergency. Results showed that personal distress was the only predictor of the decrease in motor corticospinal excitability with the increase in bystanders during an emergency. In the last experiment, a cued-reaction time task with cognitive load manipulation was used to test if personal distress was associated with a negative effect of bystanders on reflexive preparation for action. Indeed, personal distress predicted slower responses to an emergency with bystanders compared to no bystanders during a high cognitive load manipulation.

First and foremost, these results indicate that the bystander effect is not the same for every individual. The negative effect of bystanders is most apparent in people with a disposition to experience personal distress, which is a self-centered emotional reaction to the distress of others. Thus, unlike some researchers have suggested (Gilovich & Eibach, 2001; Ross, 2001), a person-by-situation interaction is possible and valid. Second, the results provide a complementary explanation for the bystander effect. When confronted with an emergency, the presence of bystanders already influences processes that are more related to reflexive, automatic consequences. The decrease in initial action preparation could be the first trigger that leads to a decrease in likelihood of helping. Diffusion of responsibility, evaluation apprehension, and pluralistic ignorance could be post-hoc cognitive interpretations of the lack of intervention by the individual. That is, the real 'bystander effect' takes place at a much lower and more reflexive level. Third, as will be explained below, the results are compatible with the Dual-Process Sequential Opponent Motivational System as proposed by Graziano and colleagues (2010; 2009).

Together with the results from **chapter 5 and 6**, the Dual-Process Sequential Opponent Motivational System provides a necessary framework to describe the effect of bystanders on reflexive action-related processes that are likely to occur before the five-step perception-to-decision model of Latané and Darley (1970). As described in **chapter 1**, two motivational but opponent systems, fight-freeze-flight system (Process A) and parental care (Process B) are activated in sequence when encountering a novel or distressful event. Crucially, personal distress and sympathy are related to the first and second system, respectively. The presence of bystanders during an emergency situation selectively increases the automatic activated Process A in people with a disposition to experience self-centered emotional reactions to distress (**Figure 2A**). As the two processes oppose each other the net effect is a dominance of Process A over B. This increased distress and activation of the fight-freeze-flight system results in situation-response decoupling and reduced preparation for action. Ultimately no helping occurs either as the consequence of a freezing response or avoidance of the situation. Of course, this is not to say to the previous explanations are obsolete. In an intriguing recent study 5-year-old children refrained from helping when other children were present (Plötner, Over, Carpenter, & Tomasello, 2015). When the other bystanders were visibly unable to help, the children did help - albeit slower than in the no bystander situation. While this suggests that diffusion of responsibility is a crucial explanation for the bystander effect, the effect of distress could run parallel to the five-step sequence of Latané and Darley (1970), and influences these more explicit processes.

Sympathy and helping behavior

Of course there are situations in which the bystander effect is less present. Dangerous situations with perpetrators present (Fischer et al., 2011), as well as in-group membership of the victim (Slater et al., 2013) reduce the bystander effect. Are there also factors within the individual that contribute to the occurrence of helping behavior? Can we find the good

Samaritan (I. M. Piliavin & Rodin, 1969)? Previous research mainly looked at the link between perception of distress and prosocial behavior (Cowell & Decety, 2015; for example Marsh et al., 2007; Marsh & Ambady, 2007). Given the results of **chapter 5** and **6** and the theoretical perspective of this thesis, a next question is if inter-individual differences in reflexive- and reflective-like behavioral reactivity to an emergency are predictive of helping behavior.

Chapter 7 combined the previously created cued-reaction time task with immersive virtual reality to predict helping behavior during a violent conflict. The experiment consisted of two parts. The participants, all supporters of F.C. Barcelona, first completed the cued-reaction time task with a low and high cognitive load manipulation, followed by the virtual reality scenario. In the midst of a conversation between the participants and a fellow supporter in a virtual bar, a supporter of a rival team started verbally attacking the fellow supporter. This conflict eventually escalated into a physical fight. During this conflict the verbal and physical interventions of the participant were measured. The outcomes were three-fold. First, participants whom reacted faster to an emergency situation under low cognitive load intervened more during the violent conflict. This was not found for behavioral reactivity measured during high cognitive load. Second, participants who described the decision to intervene as more reflex-like provided more help during the violent conflict. Third, a disposition to experience sympathy was related to a tendency to describe the decision to act as more reflex-like and importantly to a reduced distance to the perpetrator. The latter result can be seen as helping behavior by proxy.

Besides important theoretical contributions **chapter 7** provides new methodological tools and shows the value of a focus on the behavioral consequences when perceiving distress. The cued-reaction time task allows for measuring reaction times to an emergency in a covert setting and these are predictive of real helping behavior. It allows for the assessment of behavioral inclinations in a novel way both in an inter-individual and an inter-group setting. But how do the results of **chapter 7** and the first experiment of **chapter 6** fit the Dual-Process Sequential Opponent Motivational System?

The two processes of distress and sympathy (Process A and B) are sequentially activated in an individual when observing an emergency situation. For helping behavior to occur Process B needs to counteract the early inhibition of Process A on helping behavior. Graziano and Habashi (2010) describe two possibilities for this, time and repeated exposure. First, while Process A is at the beginning the sole activated system it decreases over time. This allows for the slower activated Process B to counteract Process A. One would predict that the likelihood of helping increases when sufficient time has passed. Second, repeated exposure to emergencies and other distressful situations might change the strength of the two systems in a similar way as repeated exposure to drugs (Solomon, 1980; Solomon & Corbit, 1974). Over time repeated confrontations with distress results in a decreased strength of Process A but increased strength of Process B. Moreover, Process B is activated earlier in time. The end result is a stronger

dominance of Process B over Process A, thus sympathy over distress, and care system over fight-freeze-flight system (**Figure 2B**). The results of **chapter 7** hint at the notion that a stronger disposition to experience sympathy might also facilitate the relative dominance of Process B over A. It remains elusive if a stronger disposition to experience sympathy is related to history of repeated exposure or that it reflects a natural tendency or a combination of both (Eisenberg, 2000). Exposure to distress could serve as a way to influence these opponent processes (for example Hagenaars, Mesbah, & Cremers, 2015) and ultimately increase later helping behavior. In sum, while the bystander effect is likely to affect Process A, distress, an increase in helping is linked to an increase in Process B, sympathy. Like confrontations with threat, reactions to a distressful event really seem to boil down to elements of approach and avoidance and individual differences in these motivational tendencies.

The shape of social affective neuroscience to come

This thesis comments upon a wide variety of phenomena experienced in social emotional life. Where do we, social affective neuroscientists, go from here? How do we achieve a complete understanding of active and everyday social interaction? In this last section the potential of Immersive Virtual Reality will be described, a technique that will allow a new vista on the positive and negative consequences of threat and distress perception and ultimately on human social life.

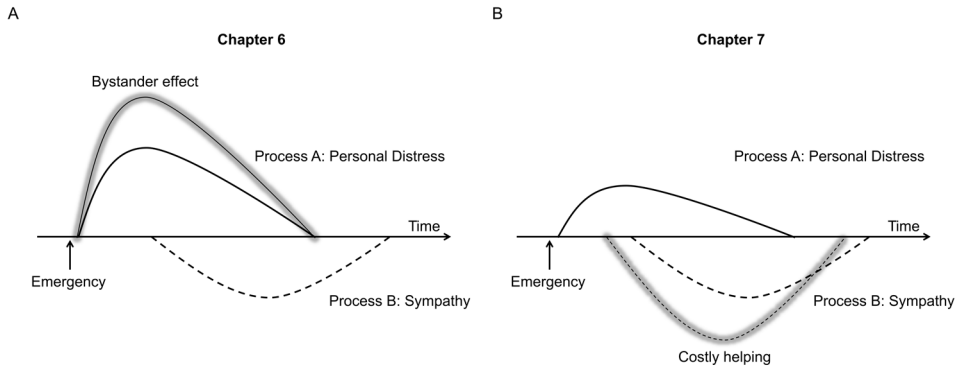


Figure 2. The effect of a disposition to experience self-centered and other-oriented emotional reactions to distress and the occurrence of helping behavior. The observation of an emergency with bystanders selectively increases Process A in people with a disposition to experience self-centered empathic reactions (A). In contrast, a disposition to experience sympathy, other-oriented feelings, results in both an earlier and enhanced activation of Process B, while simultaneously reducing Process A (B). As helping behavior is the net result of the two opposing processes the likelihood decreases when Process A is enhanced, due to a dominance of the fight-freeze-flight system over the care system. An opposite patterns is observed when Process B is increased. Figures based on the work by Graziano and colleagues (2010; 2009) and Piliavin (1982). Gray glow indicates the possible effect observed in **chapter 6** and **7**.

While the field of social affective neuroscience provides great new insight into social life, a word of caution is warranted as several weaknesses and challenges remain. A typical experiment, as reported in the literature as well as in this thesis, involves a participant explicitly labeling an emotional expression, or observing the pain of another individual, or making decisions to donate money to a third party, all in the same situational context, a computer in a room on a university campus. Topics studied in the field largely revolve around concepts focusing on internal processes, such as self-knowledge, attitudes, and theory of mind (Lieberman, 2012), and revolve around three stages of social information processing, social perception, social cognition, and social regulation (Adolphs, 2010). Arguably, several aspects need adjustments. One stage is clearly missing, social action, as the reactive aspect of social interaction is ignored, and situations used are nowhere near real life. We need an active perspective on social interaction, with a full affective loop, that studies real behavior in a variety of situations (de Gelder & Hortensius, 2014). Virtual Reality provides great promises to achieve that and **chapter 7** is a first attempt.

One of the most important psychological experiments is hard to replicate. Not because of scientific reasons, but because of ethical arguments. It is almost impossible to get ethical approval to perform an exact or relatively similar experiment. Of course, this refers to the Milgram's obedience experiment (Milgram, 1963). However using IVR Slater and colleagues (Slater et al., 2006) created an obedience paradigm and observed physiological, behavioral and phenomenological reactions as if the situation was real. IVR provides the possibility to study social behavior in situations that cannot be created in reality because of ethics, financial cost or danger to the participant or experimenter. It allows unique ways to study the neural mechanisms of threat and distress. From an attack with a knife to the hand (Gonzalez-Franco, Peck, Rodriguez-Fornells, & Slater, 2014), to witnessing a gun attack in a museum (Friedman et al., 2014), or solitary confinement in a Guantanamo Bay-like prison (la Peña et al., 2010), the possibilities are endless.

With the ultimate combination of high experimental control and profound realism (Blascovich et al., 2002), while simultaneously measuring consistent and genuine reactions in the individual despites the virtual aspect (Sanchez-Vives & Slater, 2005), IVR provides the field of social affective neuroscience with a crucial next step. Already several studies have incorporated IVR to looked at defensive responses to virtual threat as well as prosocial behavior. For example, a follow-up fMRI study on the virtual Milgram experiment showed that the perception of pain in the virtual human activated brain regions related to emotion processing, such as the amygdala, and posterior cingulate (Cheetham, Pedroni, Antley, Slater, & Jäncke, 2009). Interestingly, trait levels of personal distress influenced activity in these regions. Thereby showing the potential of IVR to elucidate the neural mechanisms of perception of and reaction to distress and the role of motivational processes in these processes.

Virtual reality also allows the embodiment of an individual in another person (Banakou,

Groten, & Slater, 2013; Peck, Seinfeld, Aglioti, & Slater, 2013; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010), going from cognitive perspective taking to first-person perspective taking, with important consequences (Maister, Slater, Sanchez-Vives, & Tsakiris, 2015). Embodiment of white participants in a black body for less then 12 minutes reduced their implicit racial bias (Peck et al., 2013). Similar changes in implicit associations to children have been observed (Banakou et al., 2013). The potential of IVR in increasing prosocial behavior has been noted. For example, the embodiment in a virtual superhero with the ability to fly increased helping behavior afterwards (Rosenberg, Baughman, & Bailenson, 2013).

As a last example of the potential of IVR for the field consider the following. While it would be impossible and unethical to repeatedly expose participants to threat or a violent conflict or bystander situations, IVR would easily allow this. For example, it could directly test the theoretical model described in the previous part. Will the repeated exposure to distress of another individual increase the second system of sympathy and decrease the strength of the first system, thereby reducing avoidance and freeze-related responses? Ultimately, incorporating IVR in the study of the social domain will provide the means to counteract the pitfalls of social affective neuroscience, while simultaneously permitting new ways to test theoretical questions that thus far have only been envisaged.

Conclusion

The work in this thesis described novel insights into the neural mechanisms of positive and negative social interactions. By incorporating a multitude of techniques and paradigms from different fields and stressing the reactive aspect of social interaction, the different chapters showed how neural and psychological processes mediate the consequences of threat and distress and how these are influenced by dispositional and situational factors. The framework of this thesis will be of great value to tackle outstanding questions and eventually allow for a full comprehension of the impact of social interactions on the individual. Or to end with the first example of the thesis, eventually we will be able to predict and manipulate the behavioral consequences of fellow commuters. Or to react with sympathy to the threat of a stressful train ride, the fellow commuter.

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Acknowledgments

> And now I'm sorry I missed you
> I had a secret meeting in the basement of my brain
>
> – *The National*

Binnen de beperktheid van de taal moet ik een weg vinden om gevoelens, gedachten, of ervaringen te verwoorden. Dit fenomenologische probleem is op te lossen. Morrissey > Science, dus aan zijn hand bewandel ik dit pad.

Dit proefschrift had niet bestaan zonder mijn promotor, Beatrice de Gelder. Bea, je moet vaak hebben gedacht "bigmouth strikes again", maar hier ben ik. De afgelopen jaren waren bijzonder, interessant, en dynamisch. Het was altijd een feest om te zien welk onderzoek we nu gingen doen, waar we heen gingen, wie ik ging ontmoeten, en hoe je me introduceerden (mijn favoriet: "my almost finished PhD friend Ruud"). Je hebt me geleerd dat het pas echt interessant wordt als mensen zeggen dat het onmogelijk is. Je leerde me de oneindigheid van de wetenschap te waarderen. Jouw enthousiasme voor de wetenschap en voor al het goede in het leven is aanstekelijk. Daarbij, jouw zorgvrije perspectief is ontnuchterend en jaloersmakend. Dank je wel voor al het vertrouwen, de vrijheid, het plezier en je besmettelijke levenslust.

Mijn copromoter, Geert van Boxtel was de rust op de achtergrond. Hoewel we niet intensief met elkaar hebben samengewerkt was je vooral in het eerste jaar daar waar ik mogelijk kon verdrinken in de oceaan van het promoveren. Het ging goed maar het was altijd fijn om te weten dat de rust een paar kantoren verderop zat.

"Some men here, they have a special interest in your career. They want to help you to grow". Dennis Schutter and Eddie Harmon-Jones. Before I started on this endeavor, you defined and kick started my career as a young scientist. Dennis, jouw enthousiasme, inspiratie, vertrouwen en geduld hebben me op dit pad gebracht. Ergens zag je de potentie in mij en je hebt dit altijd gestimuleerd. Dat je als coauteur een voorname bijdrage hebt geleverd aan dit proefschrift maakt me erg trots. Eddie, you offered me the freedom to pursue some new directions in your lab. Under your guidance the works and plays of science were revealed. You have not only learned me to balance science, but also how to enjoy it best. Science can definitely be fun.

Next, there is a whole army of scientists that contributed to this dissertation, my research, and my development as a scientist. As a coauthor, collaborator, or as committee member.

Jack van Honk, David Terburg, Dan Stein, Barak Morgan, working on the UWD project has always been stimulating and intriguing. It challenged me to reflect critically on my work, to

pursue new ideas, and appreciate different perspectives. David en Jack, jullie zijn een ander merk wetenschappers en dat maakt het erg verfrissend om met jullie samen te werken.

Wen-Jui Kuo, Nissen we have sent hundreds of emails detailing experimental procedures for new and exciting studies. It was always interesting to see where a vague idea from my side could end up. Akihiro Tanaka thank you for the possibility to use your lab to explore some new questions in my research.

Frans de Waal, Mel Slater, Mavi Sánchez-Vives, Rene Hurlemann, Alexander Sack, John Rijsman, I truly feel privileged that you serve on my committee.

I also want to thank the reviewers of my manuscripts. Especially Stephanie D. Preston. It is a wonderful experience for a young scientist to receive constructive comments from an expert in the field in an open and transparent manner. It is this process of constructive open peer review that makes science so great.

Mijn collega's van het Cognitive and Affective Neuroscience Laboratory in Tilburg en later ook het Brain and Emotion Laboratory in Maastricht. Toen ik begon waren daar Charlotte, Bernard, Lisanne en Mehrdad. Lisanne, als twee Beo's hebben we succesvol geworsteld met experimenten, fMRI, manuscripten, en promoveren in het algemeen, maar ook en eigenlijk alleen maar, veel plezier en grote avonturen beleefd. Dat dit alles zo succesvol is verlopen komt doordat jij een halfjaar eerder begonnen bent en het pad voor mij begaanbaar hebt gemaakt en ook door onze unieke beer-conomy. I probably owe you a beer. Later kwamen daar the people in Maastricht bij. Tahnée, Minye, Rebecca, Kiki, Aline, and all the others, it is always funny to see how you deal with a pretentious guy from up north like me. Luckily, Minye now starts to make jokes at my expense.

All the labs I have visited, either for research or to give a talk. The EVENT lab in particular. What a smooth operation it was. Sofía, it is such a pleasure working with you on a cool and fascinating project that keeps on growing and growing. Solène, we have so much in common and working with you on the VR project was an amazing experience. Testing football fans while discussion Houellebecq will be the new normal for science.

Naast de directe collega's, waren er andere mensen die een rol speelde. Jeroen, Mirjam, Carlijn, Jean en alle andere die me uit het isolement van Tilburg haalden. Wetenschappers rusten op een solide fundament van technische en secretariële ondersteuning, student-assistenten, interns en BSc and MSc studenten. Was het niet voor Annemay dan had ik nooit experiment na experiment kunnen draaien. Annemay, de wetenschap zal je missen. Armin of Brain Innovation, thank for your patience in explaining the nuts and bolts of BrainVoyager again and again. Dank aan SPiTS, Saskia en Diana, Christl en Riny, voor de ondersteuning van dit avontuur.

Morrissey had ongelijk wanneer hij zong “we hate it when our friends become successful”. Geert-Jan en Ronald, mijn paranimfen, jullie succes ervaar ik ‘by proxy’. Jullie hebben mij door de jaren gesteund met jullie wijsheden en relativeringen. In manische en donkere tijden. Geert-Jan, jouw openheid, eerlijkheid en ongelofelijk kennis is uitzonderlijk en stimulerend. Je bent een voorbeeld. De wetenschap heeft jouw perspectief en passie nodig. Samen voeren we de strijd tussen eigenheid en conformeren. Laten we nog vaak als Johnny Marr en Morrissey congressen bezoeken. Ronald, je hebt veel verhalen over de wetenschap moeten aanhoren. Avonden aan avonden, ik heb je zelfs even in de valkuil van de wetenschap laten trappen en dan nog sta je achter mij. Jouw talent! Het kan ook niet anders dan dat de voorkant van jouw hand komt. Je brengt de rust in de ander met jouw oneindige ratio. Jongens, jullie leren mij zoveel, ik blijf graag in jullie schaduw staan.

Dat wetenschap en vriendschap goed samen gaan liet Japan wel zien. Het overvliegen van een groep vrienden naar Okazaki City voor een onderzoek was mijn antwoord op de vraag “maar Ruud wat doe je nu eigenlijk?”. Sommige van mijn vrienden ken ik al meer dan de helft van mijn leven. Jullie weten waar ik vandaan kom, zonder opsmuk. Van schreeuwende straatpunk tot schreeuwende wetenschapper. Het is door jullie dat ik niet –altijd– naast mijn schoenen loop. Toch, Bruno, Dio, David VT, Jelle, Casper, Liset, Julia, Barend, Sander v N., Jop, Jelte, David B., Ruud M., en alle anderen? The brains of being pure at heart. Dr. Sander en Dr. Geert-Jan. Ayyayai. Onze tijd op de 20ste is voor mij het ijkpunt hoe elk lab zou moeten zijn. Femke en Ronald, het is zo fijn dat wij als huishonden in jullie leven mogen zijn. De avonden vol wijn, gesprekken over en door Ruud, en het doornemen van ‘het leven’, is alles wat een homeostase nodig heeft. Lisanne en Marie, geweldig dat ik jullie afspraken met Merel mocht verstoren door hyperactief rond te lopen en dat jullie desondanks met champagne het einde kwamen vieren.

Ooit, ver voor het promoveren, was er een voorspellend gedicht in December. Dank jullie wel Ineke en Mark, Martijn en Maja, Jeroen en Janna. Jullie interesse en gezelschap maakt het allemaal lichter. Mijn broers en zussen, ik ben zo anders, maar die ruimte geven jullie mij. Mijn ouders. Wie had dit ooit gedacht. Jullie hebben me altijd de rust en ruimte gegeven om te studeren en te doen waar mijn hoofd naar stond. Met als enige verwachting dat ik gelukkig werd. Dat ben ik. Dank jullie wel voor de vrijheid, steun en jullie trots.

Oh, the alcoholic afternoons
When we sat in your room
They meant more to me
Than any, than any living thing on earth
They had more worth
Than any living thing on earth

– *The Smiths*

Lieve Merel, door jou, voor jou, met jou en om jou. Alles is mogelijk. Elke dag zorg je ervoor dat ik het beste uit alles haal. Jouw "goedemorgen wereld", wijsheid, kracht, zorgzaamheid, unieke perspectief en je oneindige liefde. Je staat naast me. Jij brengt en bent de focus. Ergens zijn we begonnen en nu zijn we hier. We zijn zoveel geweest en gaan zoveel worden. Samen, vergroeid of verweven. De vrijheid. Het plezier. Laten nog vaak proosten op ons geluk en om beurten praten. Ik hou van jou. Jij en ik, samen. Wij. Wauw!

Curriculum Vitae

Ruud Hortensius was born on September 3rd 1983 in Wageningen, The Netherlands, and spent his childhood in and around the woods and floodplains of Elst. An underachiever in secondary school, he was retained one year but eventually managed to receive his HAVO diploma in 2001. He chose to study Social Work at the University of Applied Sciences Utrecht and he received his BSc in 2005. As he felt he wasn't ready for working life just yet, he decided to become a child psychologist instead. However, during his first year studying Psychology at Utrecht University he followed a course on the biological foundations of human behavior. It was this course, and the subsequent revelation that we are our brains, that he wanted to become a neuroscientist. With this renewed focus he received his BSc cum laude and enrolled in the Neuroscience and Cognition research master at Utrecht University in 2008. During his master's he worked with Dr. Dennis Schutter, and used a combination of electroencephalography and non-invasive brain stimulation to study neurophysiological and emotional processes. Together with Prof. Eddie Harmon-Jones at Texas A&M University, United States of America, he explored the role of the frontal cortex in aggression. Maintaining a healthy hunger for more, he started his PhD project with Prof. Beatrice de Gelder at Tilburg University in 2011. Under her supervision he studied the neural mechanisms of the positive and negative aspects of social interaction by using non-invasive brain stimulation, neuroimaging, behavioral testing, lesion studies and virtual reality. Currently, he continues to explore these topics as a postdoctoral researcher at Maastricht University, The Netherlands, and the University of Cape Town, South Africa. For a research project on African soil he received a Van der Gaag Grant from the Royal Netherlands Academy of Arts and Sciences.

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Hortensius R, Terburg D, Morgan B, Stein DJ, van Honk J & de Gelder B (2016). The role of the basolateral amygdala in the perception of faces in natural contexts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 20150376.

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Hortensius R, Terburg D, Morgan B, Stein DJ, van Honk J & de Gelder B (under review). The neural mechanisms of threat perception after basolateral amygdala damage.

SYMPATHY FOR THE DEVIL
On the Neural Mechanisms of Threat and Distress Reactivity